DO NOT R

[redacted]

CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
Exhibit E, Para 7.3	023	LEM	NAS 9-1100	1-14-63

Type II

Z65 10793

Primary No. 760

REPORT

NO. LPR-550-7 DATE: 1 November 1964

QUARTERLY RELIABILITY STATUS REPORT

[U]

CODE 26512

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To UNCLASSIFIED

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PREPARED BY:
LEM Reliability Section

G. C. Wiesinger
CHECKED BY:
G. C. Wiesinger

C W Rathke / A B Whitaker
APPROVED BY:
C. W. Rathke/A. B. Whitaker

REVISIONS

DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS

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GROUP 4. DOWNGRADED AT 3 YEAR INTERVALS; DECLASSIFIED AFTER 12 YEARS

[redacted]

ENG. 345

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

TABLE OF CONTENTS

1.0 Introduction and Summary

1.1 Introduction

Updated estimates for LEM mission success and crew safety were made during this quarter and are reported in Section 3.3. These are .90 and .995 for mission success and crew safety respectively. Comparison of apportionments and estimates are reported in each subsystem section. Because of present weight problems significant changes from the present configurations are being studied and may be implemented. At present simultaneous studies are underway for resizing the descent stage only, resizing both the ascent and descent stages, and maintaining the present control weights on these stages and examining mission-related, functional and mission success-related redundancy changes that would be compatible with these weight constraints and weight growth uncertainties. These studies will evaluate the impact on mission success and crew safety reliabilities for the alternate configurations and sizing policies. Thus, reliability estimates and comparisons with apportionments reported should not be used for trend analysis since design changes may occur during the next quarter.

The format of this quarterly has been changed during this period to reflect greater conformance with the results of the review of the fourth and fifth quarterly report held with MSC during the previous quarter. The major sections include program management, systems, and subsystems reliability engineering. Program Management, Section 2, is designed to indicate organization changes if and when they occur, and correlating the quarterly report with NPC-250-1 and the Reliability Program Plan. Thus, it provides visibility for evaluating conformance to the requirements of NPC-250-1 and the program plan. End-item and subsystem milestones and status are reported in the System and Subsystems sections respectively. These sections indicate schedules of the reliability tasks on end-items and subsystems, problem areas, and anticipated effort for the next quarter.

1.2 Summary

During this quarter the major effort in both the systems and subsystems groups has been in the areas of weight-reliability, configuration analysis, design reviews, proposal evaluations, reliability and maintainability specification inputs, and vendor coordination. As indicated

1.2 Summary (continued)

During this quarter the Parts Derating Policy was prepared and will form an appendix to LED-550-25, Approved Parts List and Application Guide.

The parts control program as it applies to vendor requirements has been reviewed and redefined to provide greater management control. A draft of Sections D and E of the VR was presented to MSC in September 1964.

Maintainability analysis are continuing in all subsystem areas and their status reported with each subsystem in Section 4.

The major effort in the GSE area during this quarter has been in the preparation of specification inputs, and establishing reliability requirements consistent with launch window constraints. These are reported in Sections 3.7 and 4.11.

2.0 Program Management

During this report period the Quarterly Report format has been changed to provide greater management visibility into the status of the LEM Reliability Program problem areas and reliability trends. These changes were made as a result of meeting held with MSC during the previous period to review the fourth and fifth Quarterly Reliability Status Report. The report is essentially composed of two sections: systems and subsystems. The systems section is designed to consider system aspects program elements which transcend individual subsystems, and contracted End-Items. Included in the system section are reliability program elements (tasks) milestones for each end-item. Successive reports will include the status of these efforts as these milestones are reached. The subsystem section, which includes flight hardware as well as GSE, presents the milestones of major subcontractor and supplier efforts as well as GAEC's efforts in these areas.

Table 2.1 indicates the sections of this report that can be correlated with NPC-250-1 and the GAEC Reliability Program Plan.

TABLE 2.1 (continued)

Correlation of Program Elements in NPC-250-1, GAEC Reliability Program Plan and 7th Quarterly Reliability Status Report

Program Elements NPC-250-1 and GAEC Program Plan	7th Quarterly Report
3.4 Failure Mode Effects and Criticality Analysis	Reported in Section 3.6 and each Subsystem Section 4.X.6.
3.5 Maintainability	Reported in each Subsystem Section 4.X.8.
3.6 Design Review Program	Reported in each Subsystem Section 4.X.9.
3.7 Failure Reporting and Corrective Action	Reported in each Subsystem Section 4.X.15.
3.8 Standardization of Design Practices	Not applicable See Q.C. Plan
3.9 Parts and Materials Program	Reported in each Subsystem Section 4.X.11.
3.10 Equipment Logs	Not applicable Q.C. Plan
4. Testing and Reliability Evaluation 4.1 General 4.2 Reliability Evaluation Plan	Reported in Subsystem Section 4.X.14.
4.3 Testing	Reported in Subsystem Section 4.X.14.
4.4 Reliability Assessment	Reported in System Section for CEI's 3.2, and Subsystem Section 4.X.14.
4.5 Reliability Evaluation Program Reviews	Reported in System Section for CEI's 3.2, and Subsystem Section 4.X.14.
5 Documentation	Reported in each Section and Listed in Section 5.

3.0 SYSTEM ANALYSIS

This section presents the status and schedules for efforts currently underway and for projected efforts concerning systems studies for Contracted End Items. System milestone schedules for system tasks on end-item LTA's, FTA's and LEM's are given in Section 3.1. Section 3.2 gives the reliability mission profile which is being used in specifications and lists, for each equipment, as well as the operating times being used for reliability estimates. A comparison of subsystem apportionments and present estimates, and a description of reasons for major differences are given in Section 3.3. The status of reliability paths, for mission success and crew safety, and the Reliability Estimation Computer Program which processes these paths is discussed in Section 3.4. Some of the more important trade-off studies completed or in progress during this past quarter are reported on in Section 3.5. The discussion in Section 3.6 concerns major findings, actions taken and studies being planned or already undertaken as a result of the System Failure Mode and Effects Analysis. Systems problems, including apportionment studies for Mission Essential GSE are discussed in Section 3.7. Current plans and ideas concerning System Reliability Assessment are given in Section 3.8. The status of the LEM Reliability Control Computer Program for failure reporting, parts control and test identification is discussed in Section 3.9.

TABLE 3.1.1

System Level Milestones By Vehicle

Vehicle	Preliminary Design Freeze*	Final Design Freeze*	Complete DVT & Qual.*	DR (1)	DEI (2)	DEL. (3)	I&C (4)	FRR (5)	Start of Completion of Specific Tests	Launch
LTA-1				x	x		x		x	
-2				x	x	N	x		x	
-3				x	x		x		x	
-4				x	x		x		x	
-5				x	x	W	x		x	
-6				x	x	N	x			
-7				x	x	M	x		x	
-8				x	x	M	x		x	
-9							x			
-10							x			
FTA-1				x	x	A	x	x	x	x
-2				x	x	A	x	x	x	x
LEM-1				x	x	A	x	x	x	x
-2				x	x	A	x	x	x	x
-3				x	x	A	x	x	x	x
-4				x	x	A	x	x	x	x
-5				x	x	A	x	x	x	x
-6				x	x	A	x	x	x	x
-7				x	x	A	x	x	x	x
-10	x	x	x	x	x	A	x	x	x	x

NOTES:

* The PDF, FDF, and DVT and Qual completions are worked against the LEM-10 only. However, these milestones are applicable to R&D instrumentation and the mission programs being used in earlier vehicles.

(1) Design Release occurs at Drawing Release.
(2) Design Engineering Inspection occurs at completion of final assembly.
(3) Delivery to MSC (M), AMR (A), NAA (N), or WSMR (W).
(4) Completion of Integration and Checkout.
(5) Flight Readiness Review occurs approximately one week prior to launch.

3.1 System (Contracted End-Item) Milestone Charts (continued)

7. Operational Readiness

The efforts in this area will be concentrated on enhancing the probability of launching an operational vehicle within the specified launch window. Prelaunch time-line-sequence-of-events and GSE requirements will be investigated and adjusted in order to achieve this objective. This analysis is both quantitative and qualitative.

8. GSE Apportionment

Determination of an availability goal (times to failure and repair times) for the mission essential GSE, and the apportionment of this goal to the various equipments in this category. Coordination with NAA on GFE items.

9. GSE Estimates

Determination of current inherent reliability and availability of the mission essential equipments.

10. System Failure Effect Analysis

Coordination of subsystem and equipment level failure effects analysis and vendor FEA's, and the determination of the effects on the end-items of losing various equipments and system functions.

11. GSE Failure Effect Analysis

Determination of the effects on the mission essential GSE, Apollo launch, and LEM mission of losing various MEE functions.

12. Maintainability Analysis

Development of design criteria for test checkout, inspection, and replacement of failed items, as well as scheduled maintenance. Access provisions, test points, fault isolation, etc. will be determined.

13. Reliability Assessment

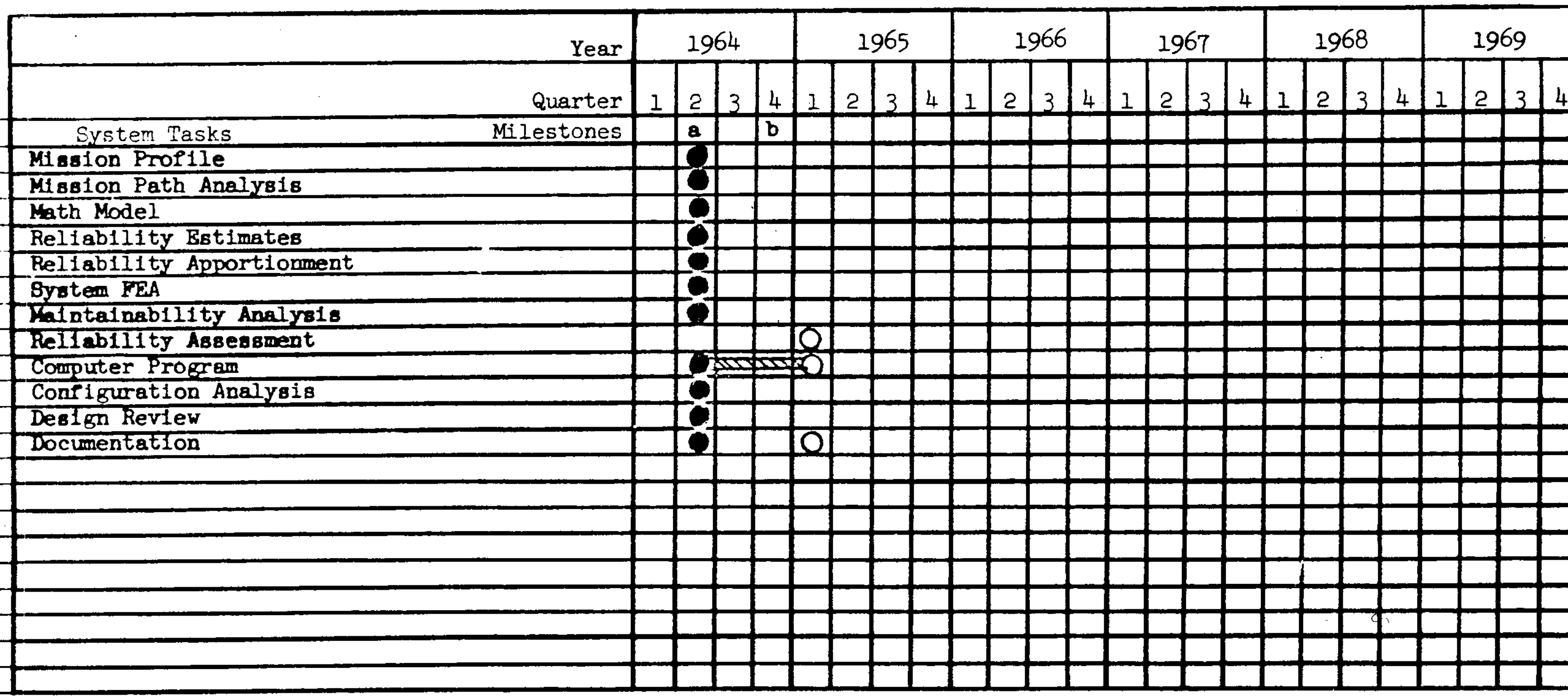
Utilization of all available data derived from program elements in order to provide a basis for decisions regarding progress to succeeding program stages, 3.1 System (Contracted End-Item) Milestone Charts (continued)

2. For LTA-2, LTA-6 and LTA-10 a white circle is used to indicate those tasks which will be completed whenever testing is completed at MSFC and NAA, respectively.

3. A line drawn between two symbols indicates a continuous effort.

CHART 3.1.2

LTA-2 System Level Milestone Chart



a DR
b DEI, I&C, Deliver to NAA

CHART 3.1.4

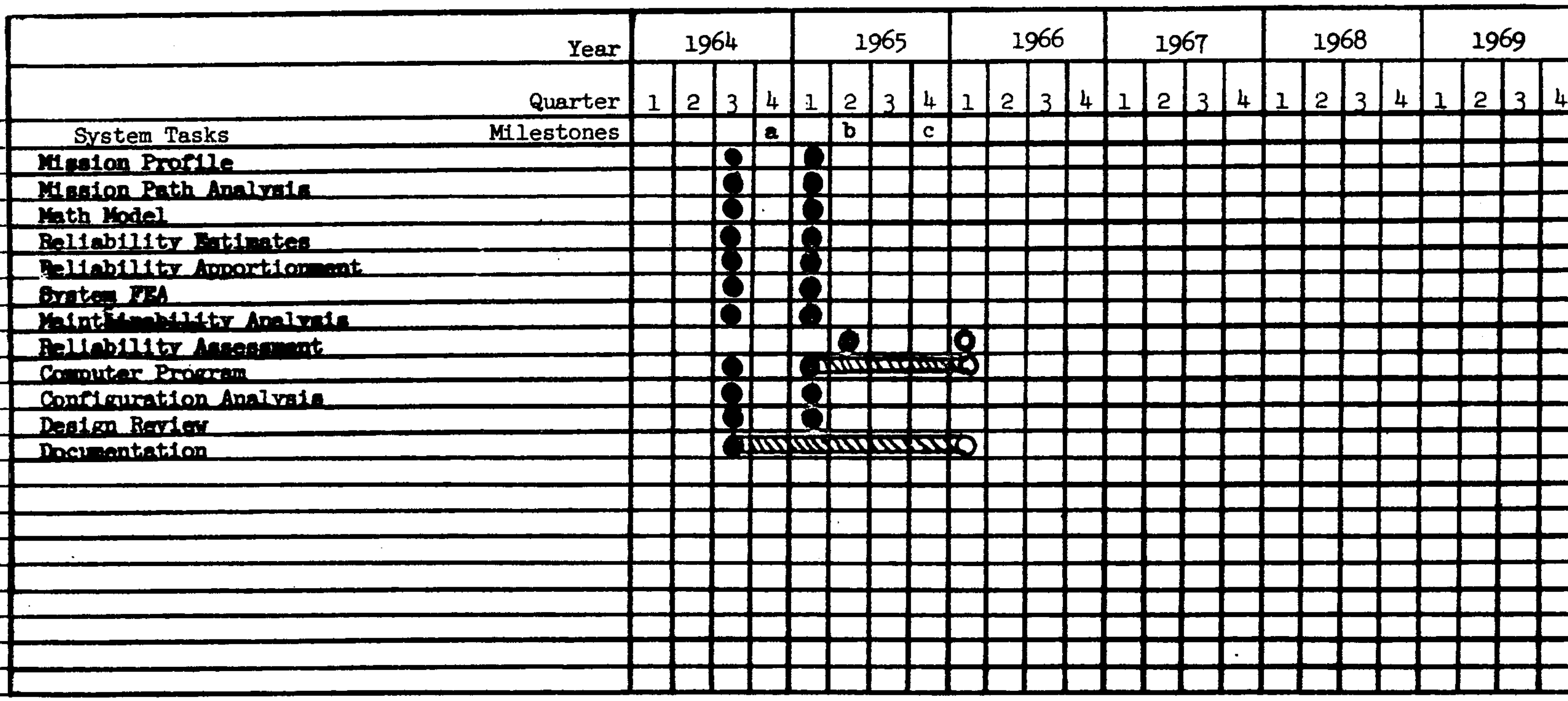
LTA-4 System Level Milestone Chart

Year	1964				1965				1966				1967				1968				1969			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
System Tasks / Milestones					a		b		c	d	e	f	g	h										
Mission Profile				●		●																		
Mission Path Analysis				●		●																		
Math Model				●		●																		
Reliability Estimates				●		●				●		●		●										
Reliability Apportionment				●		●																		
System FEA				●		●								●										
Maintainability Analysis				●		●																		
Reliability Assessment									●	●	●	●	●	●										
Computer Program				●		●								●										
Configuration Analysis				●		●																		
Design Review				●		●																		
Documentation				●										●										

a **DR**
b **DMI**
c **I&C**
d **Start EMI Tests**
e **Complete EMI and Start Vibration**
f **Complete Vibration and Start T/V Tests**
g **Complete T/V**
h **Start and Complete Impact Tests**

CHART 3.1.6

LTA-6 System Level Milestone Chart



a DR
b DMI & I&C
c Ship to NAA and Start Tests

CHART 3.1.8

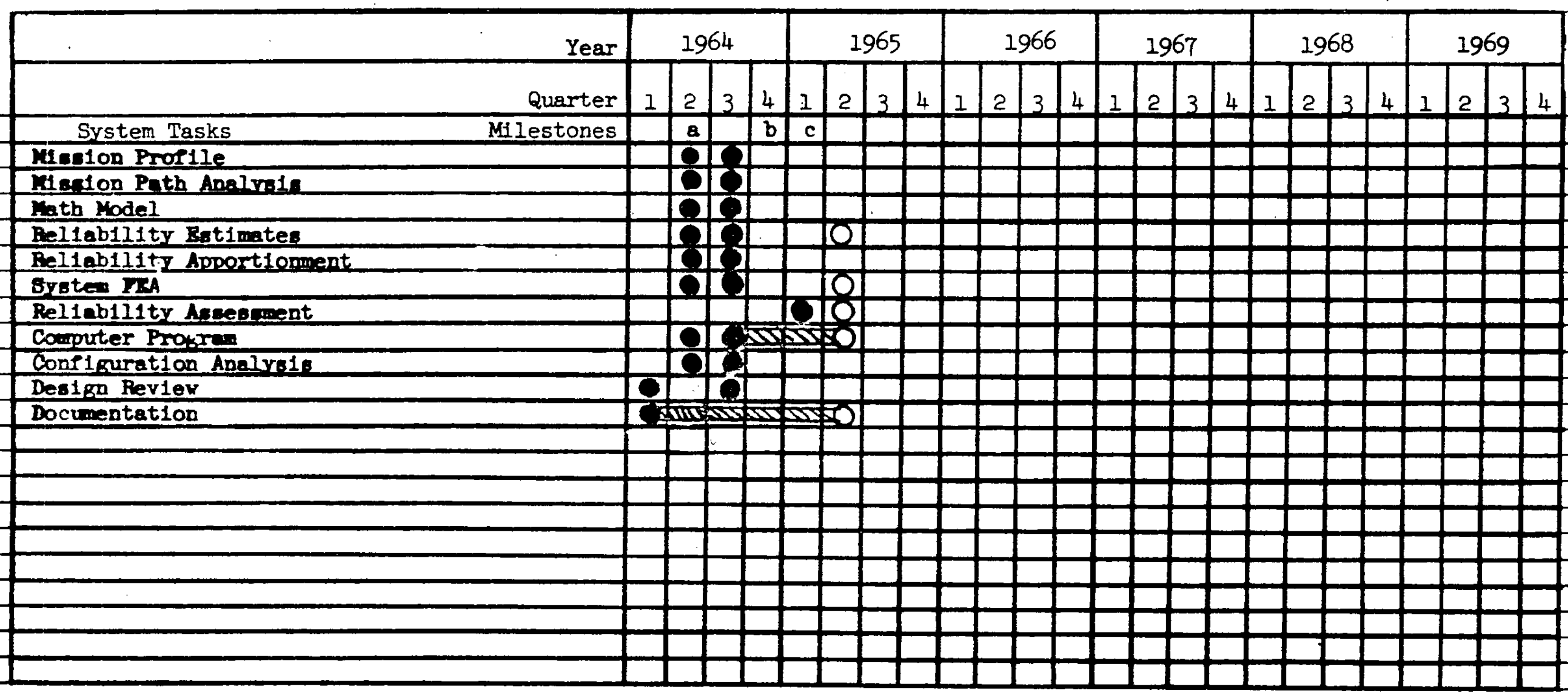
LTA-8 System Level Milestone Chart

Year	1964				1965				1966				1967				1968				1969			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
System Tasks / Milestones						a		b		c	d	e	f	g	h									
Mission Profile					●		●																	
Mission Path Analysis					●		●																	
Math Model					●		●																	
Reliability Estimates					●		●						●	●	●									
Reliability Apportionment					●		●																	
System FEA					●		●								●									
Maintainability Analysis					●		●			●	●		●	●	●									
Reliability Assessment							●								●									
Computer Program					●		●																	
Configuration Analysis					●		●																	
Design Review					●										●									
Documentation																								

a **DR**
b **DEI**
c **I&C**
d **Start Acceptance Test With ACE**
e **Arrive MSC and Start LEM/CSM EMI**
f **Complete EMI**
g **Start and Complete T/V (Unmanned), Complete Emergency Checkout Programs, Start T/V (Manned) Mission Simulation**
h **Complete Mission Simulation in T/V**

CHART 3.1.10

LTA-10 System Level Milestone Chart



a DR
b DKI
c I&C, and Deliver NAA

CHART 3.1.12

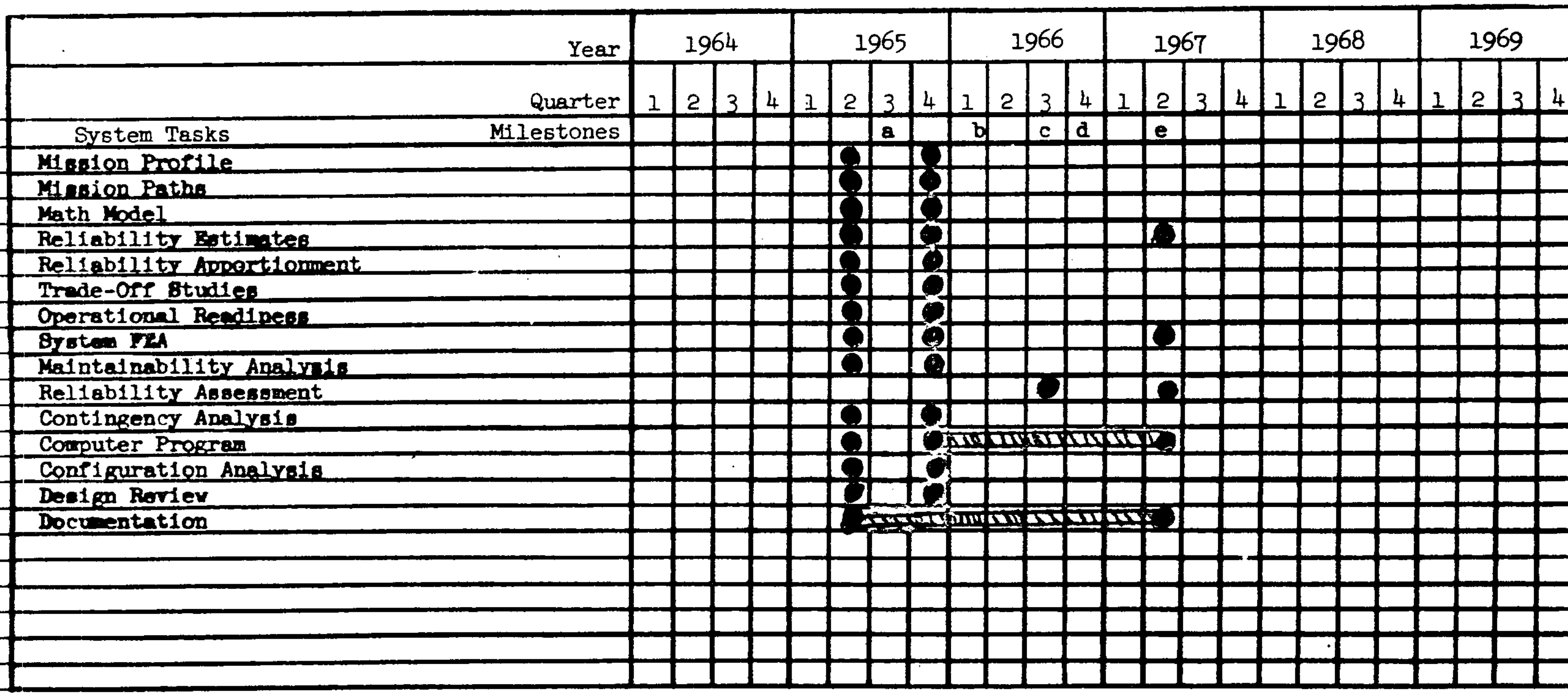
FTA-2 System Level Milestone Chart

Year	1964				1965				1966				1967				1968				1969			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
System Tasks / Milestones								a		b		c		d										
Mission Profile							●		●															
Mission Paths							●		●															
Math Model							●		●															
Reliability Estimates							●		●					●										
Reliability Apportionment							●		●															
System FEA							●		●					●										
Reliability Assessment												●		●										
Contingency Analysis							●		●															
Computer Program							●		●					●										
Configuration Analysis							●		●															
Design Review							●		●															
Documentation							●							●										

a **DR**
b **DEI and I&C**
c **Arrive AMR**
d **FRR and Launch**

CHART 3.1.14

LEM-2 System Level Milestone Chart



a DR
b DMI
c I&C
d Arrive AMR
e FRR and Launch

CHART 3.1.16

LEM-4 System Level Milestone Chart

Year	1964				1965				1966				1967				1968				1969			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
System Tasks / Milestones								a			b		c	d		e								
Mission Profile							●			●														
Mission Path Analysis							●			●														
Math Model							●			●														
Reliability **Estimates**							●			●						●								
Reliability Apportionment							●			●														
Trade-Off **Analysis**							●			●														
Operational **Readiness**							●			●														
System FEA							●			●						●								
Maintainability Analysis							●			●														
Reliability Assessment													●			●								
Contingency **Analysis**							●			●														
Computer Program							●			●						●								
Configuration **Analysis**							●			●														
Design Review						●				●														
Documentation						●										●								

a **DR**
b **DEI**
c **I&C**
d **Arrive AMR**
e **FRR and Launch**

CHART 3.1.18

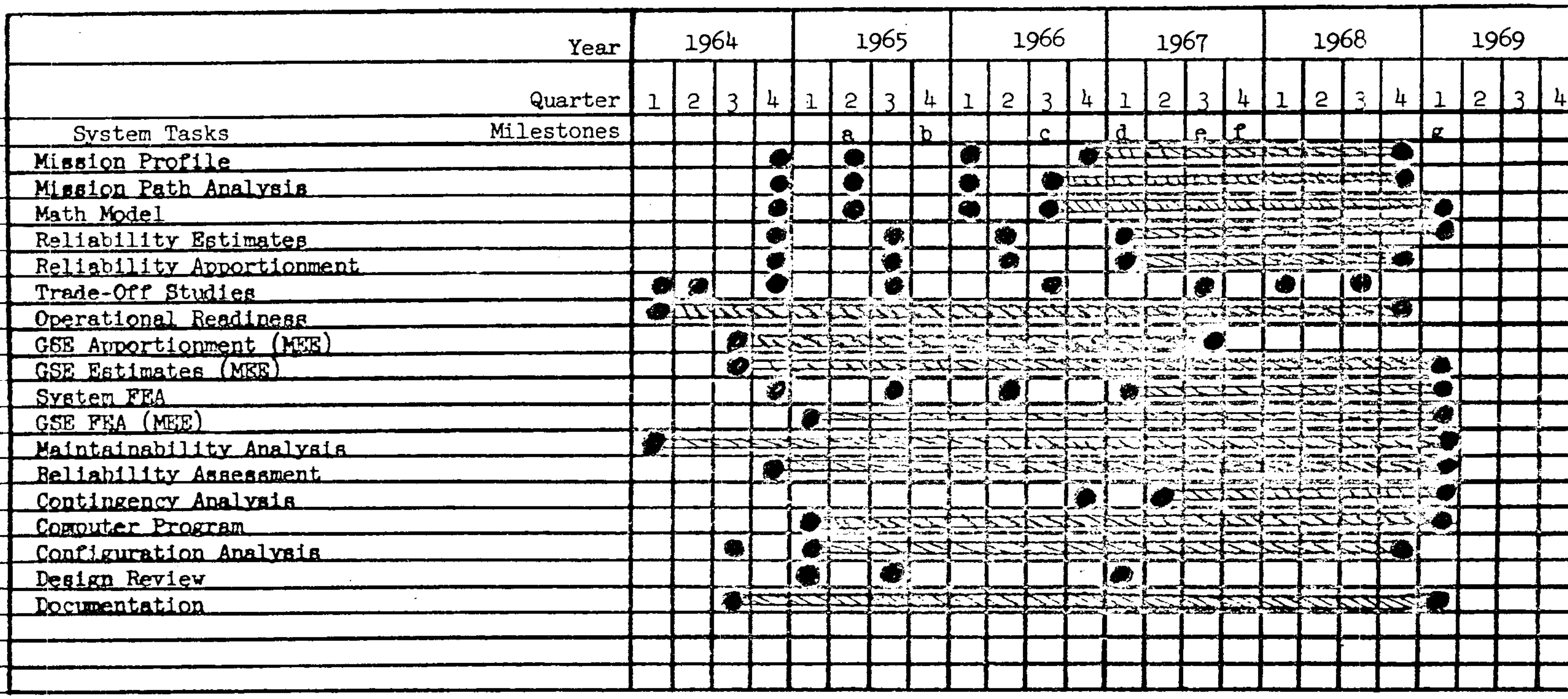
LEM-6 System Level Milestone Chart

Year	1964				1965				1966				1967				1968				1969			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
System Tasks / Milestones										a		b		c	d			e						
Mission Profile									●		●													
Mission Path Analysis									●		●													
Math Model									●		●													
Reliability Estimates									●		●							●						
Reliability Apportionment									●		●													
Trade-Off Studies									●		●													
Operational Readiness									●		●													
System FEA									●		●							●						
Maintainability Analysis									●		●													
Reliability Assessment														●				●						
Contingency Analysis									●		●													
Computer Program									●		●							●						
Configuration Analysis									●		●													
Design Review									●		●													
Documentation									●									●						

a DR
b D[illegible]
c IAC
d Arrive AMR
e FRR and Launch

CHART 3.1.20

LEM-10 System Level Milestone Chart



a Preliminary Design Freeze
b Final Design Freeze and Complete Reliability Assurance Tests
c Complete Qualification Test
d FTA and LEM Start and DR for L-10
e LEM-10 DEI and I&C
f LEM-4 Launch
g LEM-10 FRR and Launch

TABLE 3.2.1

MISSION PROFILE FOR RELIABILITY ESTIMATES

Nominal Phase	Main Phase	Mission Times		Equipment Operating Time Profile			
		Non-Boost Hours	Boost Hours	Non-Boost Oper. K=1.0	Boost Oper. K=10	Non-Boost Non-Oper. K=.001	Boost Non-Oper. K=.01
	Prelaunch	10.0					
	Earth Launch		0.197				
	Earth Orbit Through Transposition	3.8	0.087				
	Continued Translunar Trip Through Lunar Orbit Injection	72.2	0.09				
	Coast In Lunar Orbit (LEM Checkout)	4.0 (1.85)					
1	Total Pre-separation	90.0	0.374				
2	LEM Separation To Insertion	0.478					
3	Insertion And Hohmann Transfer Orbit	0.968	0.002				
4	Powered Descent From Pericynthion To Hover		0.133				
5	Hover To Touchdown		0.050				
	Post Landing Chkt.	1.25					
	Exploration	1.083					
	Prelaunch Preparation	1.667					
6	Total Lunar Stay For Mission Success Estimate	4.00					
6A	Additional Lunar Stay For Crew Safety Estimate	20.0					
7	Powered Ascent And Injection		0.093				
8	Transfer Coast	0.7					
9	Rendezvous (5 Nautical Miles To 500 Feet)	0.167					
10	Docking (500 Feet To Contact)	0.25					

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TABLE 3.2.2

EQUIPMENT OPERATING TIMES ASCENT PROPULSION SUBSYSTEM

MISSION PHASE		PRE-SEP		SEP. TO INSERT		INSERT. TO TRANSFER		POWERED DESCENT TO HOVER		HOVER TO T. D.		LUNAR STAY (N.S.)		ADDITIONAL LUNAR STAY C.S.I		POWERED ASCENT & INSERT		TRANSFER ORBIT		RENDEZVOUS		DOCKING	
PHASE TIME (HOURS)		90.374		0.478		0.970		0.133		0.050		4.000		20.000		0.093		0.700		0.167		0.250	
EQUIPMENT	OPERATING CONDITIONS	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP
HE STORAGE A	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
HE STORAGE B	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
SQUIB ACTUATED	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	—	—	—	—	—	—	—	—
ISOLATION VALVE	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
HE MANIFOLD	BOOST	—	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	0.093	—	—	—	—	—	—	—
HIGH PRESSURE	NON-BOOST	—	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	0.700	—	0.167	—	0.250	—
HE PRESSURE	BOOST	—	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	0.093	—	—	—	—	—	—	—
REGULATOR A'SSY	NON-BOOST	—	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	0.700	—	0.167	—	0.250	—
HE MANIFOLD	BOOST	—	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	0.093	—	—	—	—	—	—	—
REGULATED PRESSURE	NON-BOOST	—	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	0.700	—	0.167	—	0.250	—
QUAD CHECK VALVE	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
FUEL TANK	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
HE MANIFOLD	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
OXIDIZER TANK	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
HE. MANIFOLD	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
PRESSURE RELIEF	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
VALVE A'SSY	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
FUEL TANK AND	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
MANIFOLD	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
OXIDIZER TANK	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
AND MANIFOLD	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
ASCENT ENGINE A'SSY	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
	BOOST																						
	NON BOOST																						
	BOOST																						
	NON-BOOST																						

TABLE 3.2.4

EQUIPMENT OPERATING TIMES EPS SUBSYSTEM

MISSION PHASE		PRE · SEP		SEP. TO INSERT		INSERT. TO TRANSFER		POWERED DESCENT TO HOVER		HOVER TO T.D.		LUNAR STAY (A.S.)		ADDITIONAL LUNAR STAY (C.S.)		POWERED ASCENT & INSERT		TRANSFER ORBIT		RENDEZVOUS		DOCKING	
PHASE TIME (HOURS)		90.374		0.478		0.970		0.133		0.050		4.000		20.000		0.093		0.700		0.167		0.250	
EQUIPMENT	OPERATING CONDITIONS	OP.	NON OP	OP.	NON OP	OP.	NON OP	OP.	NON OP	OP.	NON OP	OP.	NON OP	OP.	NON OP	OP.	NON OP	OP.	NON OP	OP.	NON OP	OP.	NON OP
ASH_2 -1	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
ASH -2	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
ASOX	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
DSOX	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	—	—	—	—	—	—	—	—
	NON-BOOST	90.001	—	0.478	—	0.968	—	—	—	—	—	4.000	—	19.000	1.000	—	—	—	—	—	—	—	—
DSH_2	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	—	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	19.000	1.000	—	—	—	—	—	—	—	—
AB	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
FUEL CELL	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
ESS	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
PDL	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
BUSS	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
INVERTER	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
BATT CHARGER	BOOST	—	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	—	—	—	—	—	—	—
	NON-BOOST	—	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	13.500	6.500	—	—	—	—	—	—	—	—
PYRO BATTERY	BOOST			OPERATING TIME NOT APPLICABLE. OPERATION COULD BE EXPRESSED IN TERMS OF NO. OF PULSES																			
	NON BOOST																						
PYRO DIST. SYST.	BOOST			OPERATING TIME NOT APPLICABLE OPERATION COULD BE EXPRESSED IN TERMS OF NO. OF PULSES																			
	NON BOOST																						
	BOOST																						
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TABLE 3.2.6

EQUIPMENT OPERATING TIMES E.C.S. SUBSYSTEM

MISSION PHASE		PRE-SEP		SEP. TO INSERT		INSERT. TO TRANSFER		POWERED DESCENT TO HOVER		HOVER TO T.D.		LUNAR STAY (L.S.)		ADDITIONAL LUNAR STAY (C.S.)		POWERED ASCENT & INSERT		TRANSFER ORBIT		RENDEZVOUS		DOCKING	
PHASE TIME (HOURS)		90.374		0.478		0.970		0.133		0.050		4.000		20.000		0.093		0.700		0.167		0.250	
EQUIPMENT	OPERATING CONDITIONS	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP	OP.	NON-OP
O_2M	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	3.000	87.000	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
CAR	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	3.000	87.000	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
GOX	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000		0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
SC	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	3.000	87.000	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
SS	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	3.000	87.000	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
PLSS	BOOST	—	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—
	NON-BOOST	—	90.000	—	0.478	—	0.968	—	—	—	—	1.083	2.917	10.000	10.000	—	—	—	0.700	—	0.167	—	0.250
DH_2O	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	—	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	2.333	1.667	20.000	—	—	—	—	—	—	—	—	—
AH_2O	BOOST	—	0.374	—	—	—	0.002	—	0.133	—	0.05	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	—	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	0.700	—	0.167	—	0.250	—
H_2OM	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
HT_1	BOOST	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	90.000	—	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
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TABLE 3.2.8

EQUIPMENT OPERATING TIMES COMMUNICATIONS (LESS VHF) SUBSYSTEM

MISSION PHASE		PRE-SEP		SEP. TO INSERT		INSERT. TO TRANSFER		POWERED DESCENT TO HOVER		HOVER TO T.D.		LUNAR STAY (A.S.)		ADDITIONAL LUNAR STAY (C.S.)		POWERED ASCENT & INSERT		TRANSFER ORBIT		RENDEZVOUS		DOCKING	
PHASE TIME (HOURS)		90.374		0.478		0.770		0.133		0.050		4.000		20.000		0.093		0.700		0.167		0.250	
EQUIPMENT	OPERATING CONDITIONS	OP.	NON-OP.	OP.	NON-OP.	OP.	NON-OP.	OP.	NON-OP.	OP.	NON-OP.	OP.	NON-OP.	OP.	NON-OP.	OP.	NON-OP.	OP.	NON-OP.	OP.	NON-OP.	OP.	NON-OP.
TV CAMERA	BOOST	—	0.374	—	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—
	NON-BOOST	—	90.000	—	0.478	—	0.968	—	—	—	—	4.000	—	20.000	—	—	—	—	0.700	—	0.167	—	0.250
PMP	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	—	90.000	0.478	—	0.968	—	—	—	—	—	4.000	—	20.000	—	—	—	0.700	—	0.167	—	0.250	—
	BOOST	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	NON-BOOST	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	BOOST	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	NON-BOOST	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
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TABLE 3.2.10

EQUIPMENT OPERATING TIMES N&G/S&C SUBSYSTEM

MISSION PHASE		PRE SEP		SEP TO INSERT		INSERT. TO TRANSFER		POWERED DESCENT TO HOVER		HOVER TO T.D.		LUNAR STAY (A.S.)		ADDITIONAL LUNAR STAY (C.S.)		POWERED ASCENT & INSERT		TRANSFER ORBIT		RENDEZVOUS		DOCKING	
PHASE TIME (HOURS)		90.374		0.478		0.970		0.133		0.050		4.000		20.000		0.093		0.700		0.167		0.250	
EQUIPMENT	OPERATING CONDITIONS	OP.	NON-OP	OP.	NON OP.	OP.	NON-OP	OP.	NON OP	OP.	NON OP	OP.	NON OP	OP.	NON-OP	OP.	NON-OP	OP.	NON OP	OP.	NON OP	OP.	NON-OP
ΔVx	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	1.433	88.567	0.478	—	0.968	—	—	—	—	—	2.917	1.683	—	20.000	—	—	0.700	—	0.167	—	0.250	—
CPA_{SW}	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.520	87.480	0.478	—	0.968	—	—	—	—	—	2.500	1.500	—	20.000	—	—	0.700	—	0.167	—	0.250	—
CPA	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.520	87.480	0.478	—	0.968	—	—	—	—	—	2.500	1.500	—	20.000	—	—	0.700	—	0.167	—	0.250	—
ES	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.520	87.480	0.478	—	0.968	—	—	—	—	—	2.500	1.500	—	20.000	—	—	0.700	—	0.167	—	0.250	—
ATCA	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.520	87.480	0.478	—	0.968	—	—	—	—	—	2.500	1.500	—	20.000	—	—	0.700	—	0.167	—	0.250	—
CES-P/S	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.520	87.480	0.478	—	0.968	—	—	—	—	—	2.500	1.500	—	20.000	—	—	0.700	—	0.167	—	0.250	—
RGA	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.620	87.480	0.478	—	0.968	—	—	—	—	—	2.500	1.500	—	20.000	—	—	0.700	—	0.167	—	0.250	—
AC	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.520	87.480	0.478	—	0.968	—	—	—	—	—	2.500	1.500	—	20.000	—	—	0.700	—	0.167	—	0.250	—
TC	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.520	87.480	0.478	—	0.968	—	—	—	—	—	2.500	1.500	—	20.000	—	—	0.700	—	0.167	—	0.250	—
DECA	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	—	—	—	—	—	—	—	—
	NON-BOOST	0.167	89.833	—	0.478	0.968	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
GDA	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	—	—	—	—	—	—	—	—
	NON-BOOST	0.167	89.833	—	0.478	0.968	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AEI	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	1.433	88.567	0.478	—	0.968	—	—	—	—	—	2.917	1.083	—	20.000	—	—	0.700	—	0.167	—	0.250	—
ARA	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.250	87.750	0.478	—	0.968	—	—	—	—	—	2.250	1.750	—	20.000	—	—	0.700	—	0.167	—	0.250	—
PROGRAMMER	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.250	87.750	0.478	—	0.968	—	—	—	—	—	2.250	1.750	—	20.000	—	—	0.700	—	0.167	—	0.250	—
AGS	BOOST	—	0.374	—	—	0.002	—	0.133	—	0.050	—	—	—	—	—	0.093	—	—	—	—	—	—	—
	NON-BOOST	2.250	87.750	0.478	—	0.968	—	—	—	—	—	2.250	1.750	—	20.000	—	—	0.700	—	0.167	—	0.250	—

[redacted]

3.3.4 Navigation and Guidance - Stabilization and Control

Detailed studies involving the integrated guidance and control (DAP) concept are presently underway. It is anticipated that the outgrowth of these studies will indicate improvement in the Guidance and Control functional capabilities as well as an increase in estimates of mission success and crew safety probabilities.

In accordance with the studies performed to date no clear decision has been made as to the value of the DAP system (see Section 3.5 of this quarterly). New configurations are being considered, however, and it is upon these designs that the anticipation is based.

3.3.5 Environmental Control

The unreliability of this subsystem is essentially due to the long operating time required for ECS equipments. Studies are presently underway evaluating the possibility of turning off the coolant loop during translunar flight (see Section 3.6 of this report). This change could reduce the MS unreliability since the MS operating time on the coolant loop would be reduced by approximately seventy-five percent (75%).

3.4 Reliability Paths and Mathematical Model

3.4.1 Reliability Paths

The mission success and abort paths which are currently being generated on a subsystem and system level play an integral part in both the qualitative and quantitative reliability analyses. They are used not only to estimate reliability but to point out weak link equipments or parts (i.e., single or double equipment failures which may prevent mission success or jeopordize the crew).

Effort on the path analysis has been directed along three lines:

1. Review and, if necessary, update the paths already completed and reported on in the previous quarterly report (See Section 3.5.1).
2. Determine the paths for those subsystems and groups of subsystems where paths had not been previously determined.
3. Development of abort paths for all mission phases.

During this quarter MSC has modified its ground rules now requiring an abort upon the failure of any one of the three (3) fuel cells during any phase through descent. Thus, the EPS power generation paths have been rewritten to reflect this change of ground rules.

The RCS thruster paths, although complete, were found to be too numerous to be handled efficiently by computer techniques. A technique was developed, based on these paths (and using failure cuts), which simplifies estimation of RCS thruster reliability. A report describing this technique will be issued during the next quarter.

A study to redefine the Descent Propulsion paths at a lower equipment breakdown is still in progress.

With respect to item 2, studies to define paths for other subsystems are in progress. Mission success paths have been determined for the functions of EPS and ECS not covered by LED-550-30. Mission Success paths have been written for the Communications Subsystem. Preliminary crew safety (abort) paths have been determined for Guidance and Control, Propulsion, EPS, ECS, and RCS.

3.4.2 Computer Program (continued)

and the t is the time of the phase. A subroutine of the program which writes the tapes converts the K, λ , and t into reliabilities (probability of success) in accordance with the formula $R = e^{-K\lambda t}$. These converted inputs are stored on another tape for use with the major portion of the program. The original tape with the K, λ , t inputs is left intact. These inputs can be updated in accordance with the latest estimates by a subroutine of the program.

One approach to the redundancy problem would be to treat redundant equipments separately giving each an individual code number. However, if each redundant equipment was treated as a distinct element then the number of paths which the main program would have to evaluate would double for each redundant equipment. This would result in a significant waste of computer time as well as time required to prepare the input data. Furthermore, computational accuracy would be decreased. Thus, an auxiliary 1620 program has been developed and used particularly whenever redundant equipments are considered.

For the case of redundant equipments this 1620 program converts K, λ , t inputs into reliabilities based upon conditional probabilities; For each phase i the conditional probability of at least one of two equipments working through the ith phase given that at least one of two equipments worked through the (i-1)th phase is computed. Thus, the product of these reliabilities up to any phase gives the probability that at least one of two equipments works through that phase. This is the input required by the main program. The 1620 program automatically punches these calculated reliabilities out on cards in the format required by the card input option of the main program.

The 1620 program itself has the option of obtaining reliabilities for non-redundant equipments. Here too the resultant reliabilities are punched out on cards for use with the Reliability Estimation program. Thus, the card option portion of the main program can be used even if data is in the form of K, λ , t by using the 1620 to do the reliability calculations and punch the cards. Since the 1620 is usually available on short term notice this 1620 program affords a means of preparing a run for the main program in a minimum amount of time.

3.5.3 Weight Reliability Trade-Off Study

The purpose of this study is to update the weight-reliability optimizations by considering all presently available alternate subsystem configurations. Given a number of alternate configurations for each subsystem the study is designed to determine that combination of subsystem configurations which forms a system having a maximum reliability and constrained to weigh less than or equal to some prescribed weight. This study will include vehicles weighing 29,500, 32,450 and 35,400 pounds at separation representing ten and twenty percent increases, respectively, over the current control weight of 29,500 pounds. It will also consider alternate ascent stage sizings. Another aim of the study is to determine if there is a need for propellant tankage resizing in order to meet reliability requirements.

From an equivalent point in the Mercury program that project experienced a weight growth of 17% to its completion. To account for such a contingency this present weight-reliability trade-off study is being performed within the constraint of 0, 10 and 17 percent growth factors for all control weights being considered. There remains yet the task of establishing weights and reliabilities of several new configurations. Once these figures are obtained the calculations will be made by digital computer. Results should be available for the following quarterly period.

3.5.4 DAP (Digital Auto Pilot) Versus the Present N&G Systems

In view of the fact that a Digital Auto Pilot (DAP) has been tentatively adapted for use in the CSM, similar consideration is anticipated for the LEM. An evaluation of the DAP and its effect on the LEM system reliability has been initiated.

Failure rates have been determined or estimated for the preliminary designs. Based upon given configurations subsystem reliabilities were estimated and compared with the present N&G/S&C System. No clear decisions have been arrived at. Revised configurations are being considered and future studies will be concerned with estimating and comparing the reliabilities of such designs.

3.5.7 PCM Studies

Studies are being carried out to evaluate both the effect of the PCM on LEM system mission success and the effect of various PCM success definitions on its reliability estimate. The system mission success model considers more than one method of information transmittal from LEM to GOSS, thus eliminating PCM failure as grounds for mission abort in the prelunar landing phases of flight. The definitions of PCM success consider variations in the amount of data loss due to partial analog or digital multiplex failures. Detailed reports describing both of these areas are completed and will be published during the next quarter.

3.5.8 Ambient vs Supercritical Helium Storage For LEM Main Propulsion Subsystem

The proposed change in the propulsion subsystems to supercritical helium storage reduces the effective LEM separation weight by approximately one thousand (1,000) pounds. Estimates indicate that a slight degradation in the subsystem reliability would result from the use of supercritical as compared with the present ambient helium storage. The results of this analysis are reported in LED-550-35 and Section 4.1 of this quarterly report. However, the application of this weight saved, in areas such as meteoroid shielding or electrical power subsystems battery sizing can provide a significant system reliability increase. This tradeoff is indicative of a system optimization process where the total system reliability is maximized rather then individual subsystems.

3.5.9 Flight System Measurement

The efforts to aid in the definition of measurements for the LEM-10 vehicle has been continued in the past quarter and extended to include all vehicles, LEM's 1 thru 10. Measurement Coordination Meetings have been held between GAEC system and subsystem engineering and NASA-MSC personnel from IRG, ASPO, IESD. Data gathered in accordance with the reliability format as described in the last Quarterly Report have been used at these informal, working-group meetings. One of the continuing efforts in this area is the task of evaluating the probability of errors and losing signal conditioners or telemetry units associated with any measurement. Trade-off studies and coordination efforts will continue during the next quarter in order to clearly define the rationale and need for each and every measurement.

3.6 LEM Failure Mode and Effect Analysis (continued)

suggested modifications in design or operational rules in the effected areas. These studies take into consideration reliability implications within such constraints as weight, cost, and scheduling. Short summaries pertaining to such studies are presented in the following paragraphs.

3.6.1 CES/RCS - Integration

It has been observed that certain failures in the RCS or ATCA produce the same or similar effects. This is true because RCS operation is highly dependent on the ATCA. This dependency, moreover, is complicated by the fact that each pair of thrusters controlled electrically by a section of the ATCA differs from the thruster pair controlled mechanically by an isolation valve in the RCS propellant feed section. For example, each such section of the ATCA may control two (2) horizontal thrusters, while an isolation valve assembly controls one of these two horizontal thrusters and a vertical thruster which is controlled by another ATCA section.

Based upon the present configuration it is apparent that the failure logic feature of the ATCA can only be employed by shutting down a pair of thrusters, via an isolation valve. Since no redundancy exists for ±Y or ±Z translation, and recalling that thruster shut-down occurs in pairs, any failure (in ATCA or RCS) that requires shutdown will cause degradation in one of the above four (4) translations.

A suggested alternate configuration which would remove most of the above mentioned complexities is being studied. Included in the suggestions are changes in thruster orientation, propellant feed and valving, manifolding, failure logic, and thruster selection logic. Presently, this configuration is being analyzed to determine its affect on system functionality as well as system reliability.

3.6.2 ATCA - Rotational Channel Selection

As an outgrowth of the above study, a suggestion was made to provide switching capability between the 3 rotational channels of the ATCA. It was felt that if a

TABLE 3.6.1

Failure Mode and Effects Analysis Problem Status Summary

Affected Area	Problem Area	Study or Recommendation
CES/RCA	Thruster failure or ATCA failure degrades ±Y or ±Z translation of manifold precludes use of 8 thrusters.	Change in configuration including thruster orientation, manifold and propellant feed.
RCS - Propellant	Failure can cause loss of an RCS Propellant Leg.	Effect of Loss of Propellant Leg on MS and CS.
ATCA	Loss of Rotation Channels due to single failures.	Change in configuration to allow for switching among channels if failure occurs.
RCS - Propellant Tank Bladder	Difficulty in detecting bladder failures.	Failure detection schemes. Configuration changes to minimize effect of failure.
Ascent Engine Control Logic	False engine override signal precludes use of ascent engine.	Change in configuration.

3.7.1 GSE (MEE) Apportionment (continued)

as a breakdown of the mission constraints (e.g., launch windows, allowable hold times for fuel, reactants, etc.).

In order to obtain preliminary goals for each equipment, it will be assumed that all pieces of MEE are required to successfully perform their respective functions in order to launch. For the refined estimate, the detailed information will be required.

The apportionment technique will be based upon the relative effect of each equipment on the LEM mission. However, for the preliminary goals, the following approach will be followed (1) The overall goal will be apportioned to four time intervals in the pre-launch checkout period (e.g., T-70-T-24, T-24-T-15, T-15-T-8, T-8-T-0). These periods are based upon major changes in equipment utilization (e.g., removal of all carry-on GSE, etc.). The weightings assigned to the intervals increases as the interval approaches launch. (2) Each equipment in an interval is apportioned a goal based upon the ratio of its estimated failure rate to the total estimated failure rate of all equipments in the interval. (3) For equipments designated as GFE, the following procedures will be used. The apportioned (NAA) failure rates will be reviewed for compatibility with the apportioned (GAEC) interval failure rates. If they are found incompatible, the GFE goals will be reapportioned on the basis of the above described technique. The only difference will be that the NAA apportioned failure rate will be used in the calculations in place of the NAA estimated failure rate. Notification of the need for reapportionment, and its justification will be made to NAA.

The preliminary apportionments will be published during the current quarter. Updating of these goals will be performed as significant information becomes available.

3.7.2 Pre-Launch Operational Readiness

Pre-Launch Operational Readiness of the LEM System (LEM Vehicle and associated Ground Support Equipment) will be evaluated in quantitative and qualitative terms. Initial analysis will be a quantitative prediction of readiness based on evaluation of the prelaunch reliability of the system and on estimated maintenance task times.

3.8 Reliability Assessment

A reliability assessment program plan is being developed for the purpose of providing LEM management with a basis for proceeding to successive phases of the LEM design and development program. It is anticipated that the assessment plan will be completed during the next quarter.

The information required will come from all reliability program elements including vendors and associate contractors' test programs on both LEM equipments and similar equipments, the LTA and FTA programs, the LEM flight program, and NASA.

The LEM Reliability Control Computer Program will be utilized in this assessment program for the handling, storage, sorting, correlation, and presentation of results in a manner conducive to the quantitative and qualitative evaluation of the accumulated data. An effort is being made to establish the ground rules and procedures necessary for obtaining quantitative estimates of LEM reliability from this information.

The Reliability Assessment Plan will contain all applicable definitions, ground rules, program milestones for subsystems and end-items, and a status sheet showing the current status of the program milestones for each program element. An example of a Program Element Status Sheet is presented as Table 3.8.1.

The points in the individual vehicle programs at which significant quantities of data are expected to become available are shown in the System Level Milestone Charts of Section 3.1. A composite of the Reliability Assessment portions of these charts is presented below (Table 3.8.2).

The System Reliability Test group has been working with the LEM Systems Test section in order to develop the vehicle level test plans. During this quarter, reliability requirements were established and incorporated into the following test plans:

1. LTA-2 Test Plan (Preliminary), LTP-932-00001
2. LTA-5 Test Plan (Preliminary), LMO-560-125
3. LTA-7 Test Plan (Preliminary), LAV-560-78
4. TM-5 Test Plan (Preliminary), LTP-923-17001
5. LEM Vehicle Vibration Acceptance Tests (Preliminary) LTP-915-31001.

TABLE 3.8.2

Expected Times At Which Test Data Will Be Available For Reliability Assessment

Vehicles / Year	1964				1965				1966				1967				1968				1969			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
LTA-1				●	●	●																		
-2					○																			
-3				●		●		●	●															
-4										●	●	●	●	●										
-5											●		●	●										
-6									○															
-7														●										
-8											●		●	●	●									
-9											◒		◒	◒										
-10				○																				
FTA-1													●											
-2														●										
LEM-1													●											
-2														●										
-3															●									
-4																●								
-5																	●							
-6																			●					
-7																				●				

NOTE: (1) LTA-2,-6,-10 will furnish data whenever testing is completed at MSFC and NAA resp. (○)

(2) LTA-9 is considered as a backup to LTA-5. (◒)

3.9 LEM Reliability Control Computer Program (continued)

Program checkout runs commenced as soon as the failure reporting programming was finished. The initial runs primarily served a program debugging function; but in the last weeks of this quarter, failure reporting, failure analysis and corrective action data were entered, stored and retrieved from the program files with an appreciable frequency of success. Two formats were used to output data from the central failure data files. The first of these forms, a failure recurrence review, is illustrated in Figure 3. The subsystem failure summary is shown in Figure 4. Searches were made on part numbers and vendor names for both of these outputs.

The LRCP development plan was expanded from its suboptimization character during this quarter to include considerations for overall Apollo data processing requirements. One ultimate goal of the LRCP is to furnish failure information to the Apollo central data files. MSC has requested that failure data be processed onto magnetic tapes which will be sent at regular intervals to their data bank. It was also requested that the taped failure data should be in the same format used for input to the LRCP. LLR-550-41, dated 19 June described the program input formats. In order to establish a working conformity between the LRCP and the Apollo central failure data bank, sample failure reports, failure analyses and corrective action reports were processed onto MSC 729 tape #7559 and forwarded to MSC as an enclosure to LLR-550-54. This sample tape will be analyzed by the MSC Engineering Data Systems Group as part of a combined MSC-GAEC test to check and establish compatibility between the LRCP and the Apollo central failure data bank.

Development activity will continue in the next quarter aimed at attaining operational status for the parts control program and the failure reporting program. Failure data for the monthly failure summary will be forwarded, as directed, to MSC on magnetic tapes in lieu of the present typewritten document. Programming for the test identification program will be completed and debugging procedures will be implemented. This will be done in conjunction with the aforementioned activities.

FIGURE 2

LEM Where Used List

Indenture Level 1

Tag No.	Part Number	Part Name	Part Class	Vendor	Status Q C	Next Higher Assembly	Failure Rate	Quantity Vendor in Successor	Level	Tag
21	350D566X9006B2	Capacitor	G Solid Tantalum HR	56289		LDW410-64020-1			2	1
22	350D685X9035B2	Capacitor	G Solid Tantalum HR	56289		LDW410-64020-1			2	1
28	150D474X9050A2	Capacitor	G Solid Tantalum	56289		LDW410-3828			2	2
29	150D226X9050S2	Capacitor	G Solid Tantalum	56289		LDW410-3828			2	2
30	150D335X9050B2	Capacitor	G. Solid Tantalum	56289		LDW410-3828			2	2

FIGURE 4

Failure Summary Report

Subsystem Name: Sensors and ATCU Drawing Number S-30139133-S

Failure Report Number	Failure Report Date	Failure Site	Failure Report Source	Next Higher Assembly	Part Name	Part Number	Part Vendor	Cause	Elapsed Time	Analysis/ Correct. Report	Responsible Activity
FST - 3895	9-7-64	Vendor Supplier	15562	Earth Horizon Detector	Lens	G35793 A	15562	Human	11 H	AST3895/ CST3895	15562
FRY - 3921	9-8-64	Vendor Supplier	04164	Power Supply	Battery	B365832	04164	Wearout	33 H	ARY3921/ CRY3921	04164
FMI - 1104	9-9-64	Vendor Supplies	80230	Antenna	Resistor	R76321	07076	Design	320 H	AMI1104/ CMI1104	80230

4.0 SUBSYSTEM ANALYSIS

4.0.1 General

Reliability as a member of LEM Systems Engineering has had considerable impact on design decisions made on the LEM project. The sections which appear below point out the effort that is involved in deciding on which one of any number of candidate configurations (on any equipment level) should be chosen.

The general practice in performing a configuration analysis is the following:

a. Research of failure rates

b. Analysis of mission profile of configuration

c. Calculate reliabilities and check sensitivity of system reliability to questionable failure rates

d. Optimize configuration reliabilities with other vehicle design constraints.

e. Perform a qualitative analysis on each configuration.

Prior to calculating the configuration MTBF's every attempt is made to research every failure rate used, in order to assure that there is sufficient substantiating data and that the sources are bona-fide.

A careful analysis is then made of the mission operating cycle of the equipment being studied. Equipment checkout and function time during the mission is verified, based on the mission profile of the vehicle and discussion with cognizant systems and subsystems personnel.

Calculating the reliability of a configuration is not merely summing the part failure rates. In order to determine the inherent reliability of an equipment, the following must be ascertained:

a. Must all elements function in order for the equipment to operate? For example, the ATCA jet select logic can operate through the Combinational Logic or if there is a failure it can operate through the Failure Logic. The reliability analysis must take this redundancy into account.

TABLE 4.0.2.1

Elapsed Time Indicator Equipment of
1000 Hours & Greater Operating Life

Subsystem Assembly	Electro-Mechanical Indicators
Navigation & Guidance Subsystem	
Rendezvous Radar Electronic Assembly	1
Rendezvous Radar Antenna Assembly (Electronic Package)	1
Transponder Electronic Assembly	1
Landing Radar Electronic Assembly	1
Landing Radar Antenna Assembly (Electronic Package)	1
Stabilization & Control	
Rate Gyro Assembly *	2
Control Panel Assembly	1
Attitude and Translation Control Assembly	1
Descent Engine Control Assembly	1
Abort Guidance System	
Abort Sensor Assembly	1
Abort Electronic Assembly	1
8-Ball *	2
Electrical Power Subsystem	
Inverter	1
PLSS Battery Charger	1
Communications	
S-Band Transponder	1
VHF Transceiver	1
Inter-Communication	1
Steerable Antenna Electronics	1
PMP	1
Reaction Control Subsystem	
Propellant Quantity Gaging	2
* Redundant or probably redundant	

4.1 Propulsion Subsystems

4.1.1 General

Table 4.1.1.1 lists propulsion subsystem components and selected vendors.

4.1.1.1 Subcontractor Status and Milestones

Tables 4.1.1.1.1 through 4.1.1.1.3 indicate the program status and milestones for LEM main propulsion engine contractors.

4.1.2 Propulsion Subsystems Summary

4.1.2.1 Summary of Effort For Period

During this report period a study of the effects on subsystem reliability of a proposed configuration change from ambient to supercritical helium storage for the main propulsion subsystems was completed (Reference LED-550-35). This study was referenced in a program plan prepared in response to NASA letter EP64-370 dated 28 July 1964.

Effort has continued in the following:

a. Preparation of a Failure Mode and Effect Analysis of the propulsion subsystems.

b. Review of design proposals for propulsion subsystem components submitted by prospective vendors.

c. Monitoring of vendor reliability program implementation.

Maintainability effort included completion of the Maintainability Analysis, Fixed Injector Descent Engine (LED-550-34, dated 8-12-64), review of the Ascent Engine Support Manual (Bell Report 8258-954001), and review of several maintainability analyses from suppliers. In addition, the Rocketdyne Fixed Injector Descent Engine Maintenance Plan was reviewed. Direction was given to indicate maintenance limitations at a lower level of assembly.

Reliability interface meetings, with the respective vendors of the descent engine, were held at Rocketdyne and STL from 31 August 1964 through 4 September 1964. Minutes of the meetings were prepared by the GAEC Reliability personnel attending. (Reference LMM-550-9 and LMM-550-10)

TABLE 4.1.1.1 (continued)

Subcontractor Status and Milestones

Equipment	Ascent	Descent	Purchase Order	Spec. No.	Contractor
Filter, Fuel, In-Line Non-By-Pass		x	2-74652	LSP-270-807A	Aircraft Porous Media, Inc.
Filter, Oxidizer, In-Line Non-By-Pass		x	2-74653	LSP-270-808A	Aircraft Porous Media, Inc.
Tank, Helium, Storage		x	LVR-270-811	LSP-270-811	To be selected
Coupling, Helium Fill & Test Point Disconnect	x	x	3-06001	LSP-270-813A	Schulz Tool & Mfg. Co.
Filter, Helium, In-Line Non-By-Pass		x	2-74656	LSP-270-814A	Aircraft Porous Media, Inc.
Valve, Helium, Latching, Solenoid, Operated		x	3-06003	LSP-270-815A	Schulz Tool & Mfg. Co.
Valve, Helium, Press. Reducing		x	2-92818	LSP-270-816A	Sterer
Valve, Helium, Quad Check	x	x	2-92816	LSP-270-817A	Parker Aircraft Company
Valve Helium, Pressure Relief and Burst Disc		x	2-92824	LSP-270-818A	Parker Aircraft Company
Valve, Helium, Explosive Operated		x	2-92188	LSP-270-819A	Pelmec

Table 4.1.1.1.2

SUBCONTRACTOR STATUS
and Milestones

Subcontractor Rocketdyne
Spec. No. LSP 270-4A
Vendor Requirement
Document No.
Purchase Order No. 2-18827 C

Equipment Descent Rocket Engine
Date 25 April 1963
Date
Date 30 December 1963

Milestones	Jan. 1964	2	3	4	5	6	7	8	9	10	11	12	Jan. 1965	2	3	4	5	6	7	8	9	10	11	12	Jan. 1966
Program Plan	Received	Accepted																							
Reliability Status Report							Unacceptable - Minor Exceptions																		
Apportionments & Estimate							Unacceptable - Minor Exceptions																		
Math Model																									
Configuration Analysis				Accepted	Accepted	Accepted	Received	Due	Received																
Failure Mode & Prediction Anal.									Received																
Failure Effect Analysis									Received																
Maintainability Analysis							Received																		
Design Review						Accepted	Accepted	Accepted	Accepted																
Design Review Documentation																									
Circuit Analysis							Received	Received	Received																
Reliability Data List							Received		Received																
IFFAR							Received																		
Reliability Test Plan									Received																
Reliability Assessment							Received																		
Failure Reports & Corrective Action - due within one week of failure							Accepted	Accepted	Accepted	Accepted															
Failure Analysis																									
Reliability Indoctrination & Training																									→

Due △
Received
Accepted ▲

Unacceptable - Minor Exceptions
Rejected - Major Revision

4.1.2.2 Projected Effort For Next Quarter (continued)

An overall propulsion subsystem maintainability analysis will be started in the next quarter that will utilize the Maintenance Task Analysis described in Paragraph 3.7.2. In addition, a continuing investigation will be conducted into all avenues related to improving operational readiness at AMR.

The maintainability analysis in LED-550-34 will be revised to reflect the failure rates and K factors in Rocketdyne Reliability Report R-5226-3, as well as updated information on MILA test and checkout planning. It is also planned to expand the report to include the throttle valves shut-off valves and shut-off control valves. A similar analysis will be initiated on the STL engine.

Close monitoring of subcontractor and vendor reliability test programs will continue.

4.1.3 Reliability Apportionment and Estimates

The disagreement of the apportioned and estimated reliabilities listed in Table 4.1.3, exist for the following reasons:

- The failure rates used in the initial apportionment of equipment reliabilities were based on knowledge, of equipment characteristic failure rates, existing at the time of the initial apportionment.
- The present reliability estimates are based on results of a survey of failure rate information, conducted to determine the most realistic failure rate for an equipment. This survey is a continuing effort, and equipment failure rates are subject to revision as more information becomes available.

In addition to the above, the apportioned and estimated reliabilities for the complete subsystem differ because:

1. Failure modes of connecting plumbing were not included in the initial apportionments.

TABLE 4.1.3 (cont'd)

Reliability Apportionment and Estimates

Equipment	Apportioned	Estimated
Propellant Press. & Feed Subsys. (continued)		
Tank, Helium, Storage	.999847	.999994
Filter, Helium, In-Line Non-By-Pass	.999977	.999999
Valve, Helium, Latching, Solenoid Operated	.999984	.999972
Valve, Helium, Explosive Operated	.999995	.999895
Valve, Helium, Pressure Reducing	.999563	.999946
Valve, Helium, Press. Relief & Burst Disc	.999994	.999989
Detector, Propellant Level	.999985	.999995
Coupling, Fuel, Manual Disconnect, Fill & Vent	.99925	.999995
Coupling, Oxidizer, Manual Disconnect, Fill & Vent	.99925	.999995
Coupling, Helium, Manual, Disconnect, Fill & Test Point	.99925	.999995
Valve, Helium, Quad Check	.999972	.999976
Filter, Fuel, In-Line, Non-By-Pass	.999977	.999999
Filter, Oxidizer, In-Line, Non-By-Pass	.999977	.999999

4.1.3 Reliability Apportionment and Estimates (continued)

2. Equipments, with a direct effect on the application of (K) factors used in reliability calculations, present in the subsystem at the time of the initial apportionment, have since been deleted for design considerations. i.e., helium and propellant line burst discs.

3. Of revision of the original reliability mission profile to include consideration of prelaunch ready condition.

The configurations presented in the supercritical helium storage analysis (Reference LED-550-35) indicate the reliability goals apportioned for the complete ascent and descent subsystems can be approached more closely by utilization of redundant valves for isolation of the helium storage tanks. A potential area for a general increase in mission reliability lies in application of instrumentation and checkout procedures aimed at reduction of the prelaunch ready mission phase time to an absolute minimum.

The reliability estimate submitted by Bell for the ascent engine has not been utilized by GAEC for subsystem calculations. The Bell estimate (Reference Bell Report 8258-932003A) was not considered realistic for the reasons noted in Paragraph 4.1.4. Therefore, a recalculation was made by GAEC and used in determining total subsystem reliability.

The Rocketdyne engine reliability estimate decreased during this report period because of removal of the helium injection valve-close redundancy. Refinement of the analysis should improve the overall estimate.

It should be pointed out that Rocketdyne and STL are not operating on the same K factor basis and therefore, a comparison of reliability estimates for the two descent engines is not possible. Efforts are being made to correct this condition.

The STL reliability estimate is being refined on a continuing basis as details become available. The present figure for engine reliability is based on an evaluation of approximately 70% of the components. It is anticipated that the estimate will decrease as additional information is obtained.

4.1.5 Configuration Analysis

4.1.5.1 GAEC Effort

The supercritical helium storage configuration analysis (LED-550-35) was prepared to determine the effect on subsystem reliability of a proposed change from ambient to supercritical helium storage for the main propulsion subsystems. This study was referenced in a program plan prepared in response to NASA letter EP 64-370 dated 28 July 1964.

In summary LED-550-35 recommends that the supercritical helium storage configurations be utilized, in both the ascent and descent propulsion subsystems, in view of the separation weight saving effected without reliability compromise.

The estimated reliability of the supercritical helium storage configurations (Figure 6 of LED-550-35) will be approximately the same as the present ambient helium storage subsystem, if high reliability heat exchangers are utilized, and the recommendations below are followed:

a. Utilize parallel, squib actuated isolation valves downstream of helium storage tanks and upstream of heat exchangers for both main propulsion subsystems.

b. Prevent leakage of the helium storage tank pressure relief valve prior to the first overpressure by installation of a burst disc.

c. To insure that major leaks have not developed in the heat exchanger or regulation legs, during LEM mission phases prior to initiation of powered descent, pressurize the heat exchanger and regulation legs prior to earth launch, and provide instrumentation and display for astronaut mission decision.

4.1.5.2 Vendor Effort

An analysis of two helium injection valve configurations was reported by Rocketdyne during the last quarter (Reference R-5205-15 LEM Monthly Progress Report). Clarification of the analysis has been requested and is expected in the next progress report submitted.

4.1.7.1 Bell Aerosystems

A Failure Mode Prediction Analysis was received from Bell as part of their Reliability Assurance Test Plan (Bell No. 8258-932004).

The analysis was not approved by GAEC and comments have been forwarded to Bell.

4.1.7.2 Rocketdyne

A preliminary analysis has been received from Rocketdyne and is presently under evaluation by GAEC.

4.1.7.3 STL

Analyses have been received from STL as part of the following test plans:

1. Thrust Mount and Gimbal Assembly
   STL No. 8438-6118-SU000
2. Injector Assembly
   STL No. 8438-6108-SU000
3. Propellant Shutoff Valve Assembly
   STL No. 8438-6120-SU000
4. Flow Control Valve Assembly
   STL No. 8438-6123-SU000

In each case the analyses have been approved by GAEC. Comments regarding the test plans themselves are being resolved with STL.

4.1.7.4 Pressurization and Feed System

Schulz Tool Company (Purchase Order 3-06001) submitted a Failure Mode Prediction Analysis on the LSC-270-813 Coupling, Helium Fill and Test Point, Disconnect (Ascent and Descent Propulsion). The analysis was incomplete in regard to the requirements imposed by the Purchase Order (Reference Section D, Para. 3.9).

4.1.8.1 GAEC Effort (continued)

At present, it appears that the only replaceable units are transducers, probes, and parts of the electrical harness.

The Preliminary Maintainability Analysis - Prelaunch Operational Readiness of the Fixed Injector Descent Engine LED-550-34 dated August 12, 1964 was ussued. This analysis is the first example of the method of quantifying Reliability during the pre-launch phase, as described in LPR-550-6, Para. 6.1. The following is an abstract of the Introduction, Summary, and Recommendations of LED-550-34.

The servo valve, servo amplifier, helium valves, and solenoid control valves were analyzed. These four items account for 70% of the Unreliability (Q) of the Engine, based on failure rates in the preliminary Reliability Report R-5226-2 (Rocketdyne). Therefore, these items were selected as representative of the valving and controls of the engine.

For each Scheduled Event (test or checkout) the failure modes of each item were assessed and analyzed to determine the contribution of each failure mode of the total unreliability (Q).

A test which validates that a mode of failure has not developed was assumed to reduce the Q for that mode of failure to zero upon completion of the test. An estimate was also made of the Unscheduled Events (Unscheduled Maintenance Tasks) that may occur and their probability. The results were documented on three (3) types of analysis forms.

The analysis results indicate a summation Q for the four items at launch, of 20,508 x 10^{-6}. This estimate was compared to an estimated goal of 63 x 10^{-6}. In spite of the preliminary nature of the analysis, certain conclusions could be drawn. The high Q and correspondingly low Operational Readiness at Launch is a function of failure rate estimates and environmental (K) factors, the depth of Launch Pad verification testing, and the period of time from Static Firing (MILA) to Launch. A recommendation was made to increase the extent (depth) of Launch Pad testing. This approach would allow checking for more modes of failure, which would increase Operational Readiness at Launch. The recommendations included callouts for certain items of GSE needed to allow the increased testing.

4.1.8.2 Vendor Effort (continued)

Bell Aerosystems Company completed the Ascent Engine Support Manual and submitted it to GAEC for review. The Support Manual identifies replaceable assemblies, lists replacement instructions for these assemblies, and gives Checkout and Test, Servicing, and Flushing information. GAEC Maintainability has reviewed the Support Manual, and will discuss it further with Bell during a meeting to be held in the next quarterly period.

Bell completed the Reliability Plan and submitted it for GAEC review. The Maintainability portion was found to be satisfactory.

4.1.8.3 Problem Areas

GAEC Maintainability investigated the possibility of replacement of failed assemblies during prelaunch phases. Bell's Support Plan calls for replacement of transducers, probes, and parts of the electrical harness, but not the valve assembly, thrust chamber, or injector. Rapid replacement of the latter assemblies, especially at the vertical assembly building and Launch Pad, would save considerable time as compared with the destacking required for replacement of the engine. To gain this advantage the problems of Failure Detection, Isolation to the replaceable assembly, Checkout, and Revalidation must be considered. GAEC Maintainability has investigated these areas and will confer with Bell to determine the practicality of each assembly replacement.

4.1.9 Design Reviews

During this period there has been no GAEC reliability participation in design reviews pertaining to the propulsion subsystems. All propulsion component vendors, with the exception of the engine manufacturers, are contracturally required to perform formal design reviews with optional participation by GAEC Reliability.

Effort will be made during the next report period to schedule formal design reviews with the engine vendors and enable GAEC Reliability participation. At the present time, design reviews are continually being conducted on both formal and informal levels, with participation by GAEC Propulsion and/or the GAEC resident Engineering representative, and the respective engine vendors, 4.1.13.1 Bell Aerosystems (continued)

The Bell Test Plan "Reliability Assurance Test Plan and Failure Mode Prediction Analysis" was received (Bell Report No. 8258-932004).

The Test Plan was not approved (Reference LMO-550-369 and LTX-170-1489). A meeting with Bell is planned to resolve GAEC comments.

4.1.13.2 Rocketdyne

During this report period test effort at Rocketdyne was chiefly concentrated on improving throttle performance, reducing instability and optimizing helium injection techniques.

Stability tests using 6.5, 6.9 and 13.43 grain charges were run using the -11 doublet pattern and -05 triplet pattern injectors. In all cases stabilization occurred within specification requirements and there was no significant hardware damage.

Throttling and helium injection tests were run wherein helium injection flow rates were varied to both fuel and oxidizer inlets, to fuel side only, or to oxidizer side only.

A new helium dispersion top manifold injector design was also extensively tested.

As a result of these tests a decision has been made to discontinue efforts with the -11 type injector (which had been considered a backup for the -05 type). It was concluded that the -11 is generally rougher at full thrust, buzzing instability starts at a higher thrust level, and greater thrust chamber erosion occurs.

Approximately 14 engine level tests were also run. GAEC HD-2 rig was set up and the first engine tests were run.

The high altitude facility at the Nevada Field Laboratory (NFL), was checked out and the first test with a start at 90,000 feet altitude and engine operation at 124,000 feet altitude was accomplished. Throttling down to 10% thrust was successfully completed.

4.1.13.4 Feed and Pressurization System (continued)

Two Program Planning Documents were submitted by Aircraft Porous Media on the LSC-270-807 and -808 Fuel and Oxidizer Filters. Program Plans PPD-6876-24 and PPD-6876-242 have been reviewed by LEM Reliability and found to be unacceptable. Comments were sent to the responsible GAEC Propulsion Engineer with the stipulation that the items listed in References LAV-550-103 and LAV-550-160 must be resolved before the plan can be completely accepted.

Meetings were held between GAEC Design and Business personnel during the third week in June to evaluate Pelmec's Quotes on the test program for the LSC-270-714 and -819 Valve, Helium, Explosive Operated. Comments from LEM Reliability were forwarded to the Design Group and Business Office (Reference LMO-550-336 dated June 22, 1964). The open items were resolved between the Business Office and Pelmec and a purchase order was issued.

Since the explosive valve is a single cycle device, LEM Reliability requested that a total of 20 valves (10 each -714 and 10 each -819) be used for the Reliability Tests. It was ascertained that a minimum of 20 valves (and not the usual four units) are required because the single cycle operating characteristic of the valve does not permit refurbishing and retesting a smaller number of test units to achieve the desired degree of confidence. Pelmec has been directed to use 20 valves for the Reliability Boundary and Stress-to-Failure Tests.

4.1.14 Reliability Assessment

There has been no effort expended on reliability assessment during this report period.

4.1.15 Failure Reporting and Corrective Action

4.1.15.1 Bell Aerosystems

To date a total of 26 failure reports, starting from June 1964, have been received from Bell Aerosystems Co. against their ascent engine. A synopsis of these failures have appeared in the LEM Reliability monthly failure summaries dated the 15th of each month (Reference LPR-550-112 15 September 1964). All failures reported thus far have been supplemented with corrective action

4.1.15.3 Rocketdyne (continued)

After a general GAEC and Rocketdyne meeting at the latters facility,on August 31, 1964, Rocketdyne was instructed to accelerate their comments to us and close out all failures with a definite statement. Since these meetings there have been issued corrective action statements which closed out nine of the sixteen open failures. GAEC is expecting the others momentarily.

GAEC is aware that the failures to date have been predominantly the result of feasibility type tests on non flight hardware therefore, corrective action statements are not possible under certain conditions. Nevertheless, these reports are being recorded and will be part of the LEM Reliability Computer Program. The availability of this information will be on tape for any further analysis requirements.

4.1.16 Failure Analysis

There has been no effort expended on failure analysis during this report period.

4.1.17 Reliability Training and Indoctrination

There has been no reliability training and indoctrination reported by vendors during this report period.

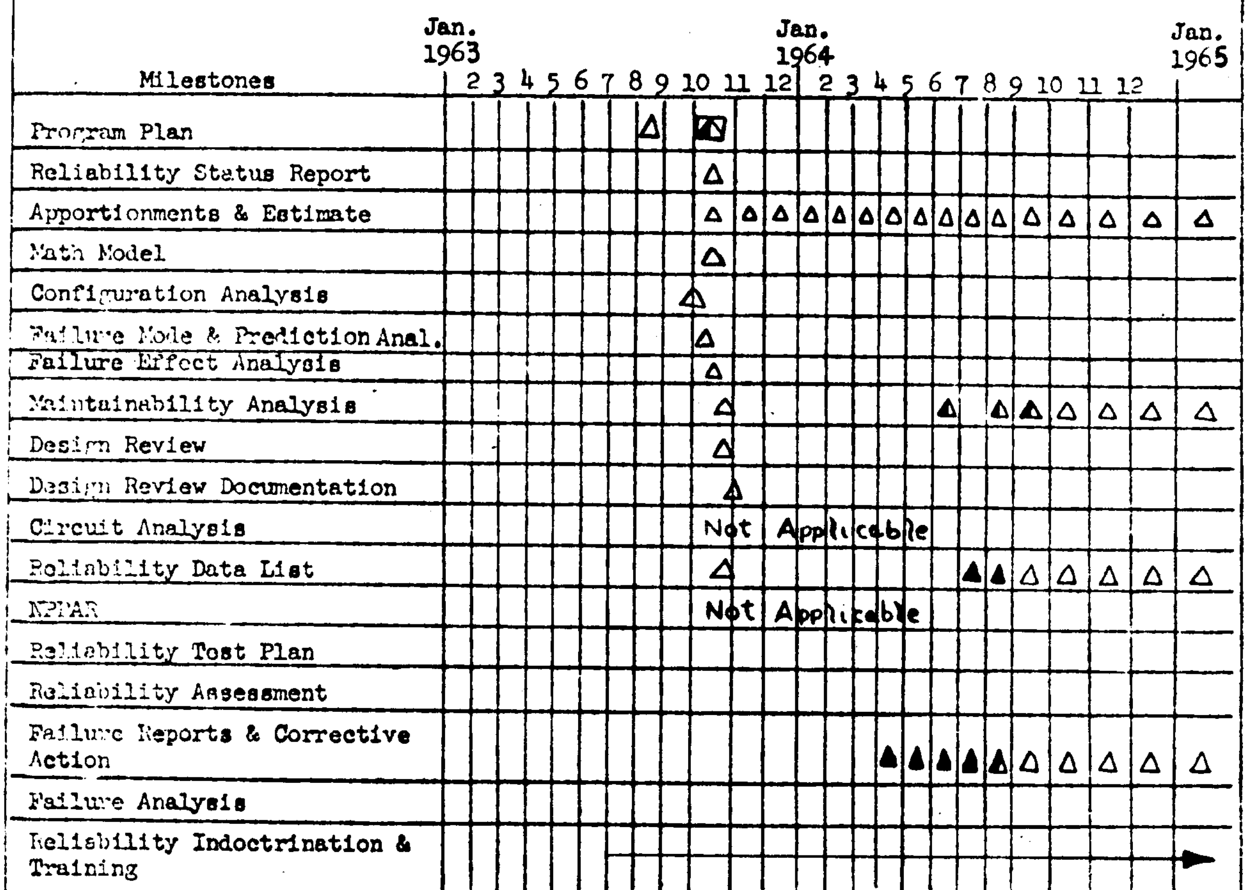
4.2.1.1 SUBCONTRACTOR STATUS AND MILESTONES

SUBCONTRACTOR STATUS

Subcontractor THE MARQUARDT COMPANY
Spec. No. LSP-310-2B (Revised)
Vendor Requirement
Document No. LVR-310-2B
Purchase Order No. 2-18831-C

Equipment RCS TCA
Date SEPT. 18, 1963

Date MAY 7, 1963
Date JULY 22, 1963



Due △
Received
Accepted ▲

Unacceptable - Minor Exceptions
Rejected - Major Revision

TABLE 4.2.1

Subsystem Analysis

RCS

Equipment	Reliability *				Weight	
	Apportioned		Estimated			
	Mission Success	Crew Safety	Mission Success	Crew Safety	Apportioned	Estimated
Helium Pressurization and Controls and Propellant Tankage	.999902	.999959	.994730	-	-	-
Thruster Installation Assembly	.999902	.999976	**.992968	-	-	-
Total RCS	.999804	.999935	.988146	.9984	-	863.0

* Not updated since last quarterly.

** Details of change will be issued in LED shortly and be explained in more detail next.

Bell - data is presently not available to determine the average number of explusion cycles possible on the bladder assemblies prior to wear-out. This will be initiated during the early stages of development test, next quarterly period, to prove out the soundness of the configuration, and tank loading changes which are characteristic of Model 8339.

4.2.3 Reliability Apportionments and Estimates

Until this past quarter Bell was developing a three ply, three mil teflon bladder, nestled together and heat sealed at the ends, for the RCS propellant tanks. The bladder design is the same as that used on the NAA command and service module tanks.

Bell informed Grumman by letter in June that during their program to finalize the configuration prior to the start of DVT two discrepancies were noted.

1. During low temperature explusion cycling of the fuel tank assemblies, higher than normal residual propellants indicated leakage between the plys.
2. During the oxidizer - fill cycle, lower than normal fill volumes indicated ply separation.

Bell recommended initiating a thorough across the board research program on bladders. At the same time they advised proceeding with a tentative selection (realizing its potential limitations) and coupling it with limited research. Another option was to make a test selection and defer any research pending the results.

Bell indicated in their service module specification a failure rate of 13000×10^{-6} per explusion cycle for single ply teflon bladders (Agena 8101 data) and speculated on a failure rate of 100×10^{-6} for a 3 mil 3 ply bladder.

The former would completely dominate the reliability model while the latter would not cause a change in the analysis of the subsystem. NASA stated that the common technology program will go single ply. LEM Reliability feels that the three-ply concept with slight modification, will give us the crew safety and mission success goals necessary to satisfactorily meet the LEM mission. It is not felt that this goal can be met with a single-ply design. It is interesting to note that Bell Reliability is basically in agreement and indicates that 99.93 percent of all tank assembly failures are bladder failures.

4.2.6 Failure Mode and Effect Analysis

The RCS Functional FMEA revealed several critical items which would have a serious effect on Mission Success and Crew Safety Reliability of LEM in the event of failure. These include the following items:

1. Explosive Actuated Helium Squib Valve

   Although valves are physically redundant, the explosive charge located in each valve may come from the same faulty lot of pyrotechnic chemical at the source thereby causing both squibs to malfunction. This condition can degrade theoretical redundancy in the system.

2. Helium Tank Relief Valve

   The effect of a rupture type of failure of a helium tank (in which helium gas is stored at 3000 PSI) would have a serious effect on both Mission Success and Crew Safety Reliability, with possible loss of LEM. The schrapnel type explosion generally associated with a high pressure gas tank rupture could conceivably rupture both adjacent fuel and oxidizer tanks causing hypergolic ignition and explosion of propellants. For this reason, a high pressure relief valve located immediately downstream of the 3000 psi helium supply is recommended for safety of crew as a safeguard against inadvertent overpressurization of helium tank. Since the helium tank is designed with a burst pressure of 7000 psi the suggested relief valve could arbitrarily be set at approximately 6000 psi to relieve excessive pressure and prevent bursting the tank.

3. Propellant Tank Bladders

   Leakage or rupture of either one of the bladders (total of 4 in. RCS) in the fuel or oxidizer tanks can cause an interchange of helium gas with the propellant resulting in erratic firing of RCS thrusters. The ensuing unpredictable RCS operation would require closing down the affected leg thereby preventing use of 50% of available propellant. This condition would have a serious effect on Mission Success Reliability requiring an abort after Separation phase in Lunar Orbit, or it would jeopardize ability to achieve a successful Rendezvous after ascent from Lunar surface is initiated.

Bell Propellant Tank FMEA

The subject analysis indicates that serious consequences can result from any one of several types of bladder failures noted below. Based on the FMEA and the related Reliability Apportionment data from Bell, it is evident that the bladder is the least reliable item in the tank assembly. In addition, the propellant bladder is "in series" with successful operation of each of the two legs that comprises the RCS subsystem, therefore, the bladder directly affects Mission Success Reliability of LEM.

Type Failure	Effects and Consequences
A. Bladder Rupture or, Bladder Loosening from Hardware of either end.	Propellant and helium gas interchange resulting in erratic operation of system. (Degradation of performance dependent on degree of failure). Requires shutdown of affected leg.
B. Helium Gas Leakage Through Bladder:	
1. Single Inner ply or Outer Ply from crease induced perferations (in 3 ply configuration at 3 mils thick per ply)	Helium or propellant becomes trapped between inner (or outer) and middle ply resulting in decrease in expulsion efficiency. ("ply separation" from propellant penetration in 3 ply bladder also has same effect).
2. Leakage from crease induced perferations in all 3 plys.	Propellant and helium gas interchange resulting in erratic operation of RCS system and probable degradation of performance (Amount dependent upon degree of failure)

4.2.7 Failure Mode Prediction Analysis

Grumman

No effort during this period.

TMC

No effort during this period.

1. Request for possible design changes which will make all temperature and pressure transducers within the cluster mounts fully accessible for removal and replacement.

2. The use of mechanical connections for same propellant tubes and brazed over for others.

3. Minor design changes on the cluster mounts in order to permit removal of the horizontal engines without the need for removing the cluster mounts from the LEM.

4. Request for a study to determine whether purging of the RCS system will be required in those cases where items with mechanical couplings are removed and replaced.

5. Preparation of input data pertaining to maintainability, accessibility, shelf life, and endurance for TMC transducer and valve design specifications.

6. GSE recommendations submitted included the addition of a solid state INH131T gate to a proposed Decontamination Scavenging System in order to permit opening and closing of individual oxidizer for fuel injector valves (rather than in pairs) during the decontamination processs.

7. The Giannini Corporation was furnished with a list of design criteria for the propellant Quantity Gauging System during a meeting held at Grumman on July 23, 1964.

   A major drawback in maintainability evaluation is that the individual assemblies and components are not available for investigation at Grumman during the R and D stage.

   Problem areas under investigation are engine accessibility, filter, replacement, purging procedures after maintenance, etc.

4.2.8.2 The Marquardt Corporation

Participation in maintainability and related efforts including the following:

1. Development tests, feasibility tests, service test models and components, design verification test and vibration tests.

2. Qualification Tests and Prototype models, Bladders and Plexiglass Tanks.

3. Reliability Plan and Vibration details.

4. Volume Verification of tank.

5. Explusion Cycle Testing (to determine bladder explusion efficiency).

6. Pressure Cycle Fatigue Tests.

7. Acceptance Tests.

8. Slosh Tests

c. Propellant vs. tank dynamics; effects of acceleration and shock.

d. Review of all drawings including:

1. Complete set for tanks (53 drawings)

2. Mockup drawings.

3. Plexiglass tank drawings (for testing).

4. Bell Aerosystems numbering system.

e. Tank assembly complete operational analysis.

f. Review of:

1. Weight calculations.

2. Vibration parameters.

3. Mounting bracket interface.

4. Preliminary stress analysis.

5. Volume calculations.

g. Reliability Assurance Plan.

h. Reliability status regarding Propellant Tank Program.

TABLE - (Reliability Data List) 4.2.2

Equipment Propellant System & Thrust — LEM System & Subsystem Reliability Data List

Reference Schematic Chamber Assemblies, RCS System 227851 — Part No. — Model No. — RCIA

1	2	3	4	5	6	7
Item No.	Ref. Design.	Description 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15.16	Component Part No.	Procurement Specification	Manufacturer	Qty. Per Unit
1		Cluster Assembly - Thrust Chamber PS/TCA (Right Hand)	227853			2
2		Cluster Assembly - Thrust Chamber PS/TCA (Left Hand)	227854			2
3		Thrust Chamber Assembly - Bi-Propellant, Reaction Control	227855			4
4		Propellant Filter-Cluster, Thrust Chamber	227856	EPS-155		4
5		Pressure Transducer-Chamber, Combustion	227857			4
6		Temperature Transducer-Injector Head, Thrust Chamber	227858			4
7		Pressure Transducer-Propellant Line, Cluster	227859			4
8		Temperature Transducer-Propellant Line, Cluster	227860			4
9		Shutoff Valve-Fuel Solenoid Cluster Isolation	227862	EPS-159	Eckel Valve San Fernando	8
10		Shutoff Valve-Oxidizer Solenoid Cluster Isolation	227863	EPS-159	Eckel Valve San Fernando	8

Section V (Reliability Testing Program) of the TMC Reliability Program Plan was reviewed and disapproved (LMO-550-374). Specific areas of disapproval centered around TMC's interpretation of failure reporting and the method of determining critical stresses for stress-to-failure tests.

Section VI (Reliability Testing Program Data Analysis) of the TMC Reliability Program Plan was reviewed and disapproved (LMO-550-411). The statistical methods proposed by TMC were vague and inadequate. The plan did not present the methods of data analysis in sufficient detail for a comprehensive review.

4.2.13.3 RCS Propellant Tankage - Bell

No testing on LEM propellant tanks was conducted during the reporting periods. The entire RCS tank program was held up until the bladder failure problem being experienced by NAA was resolved.

The Bell RCS propellant tank Program Plan was received. Review of the General Test Plan (which contained the Reliability Assurance Test Plan) was completed and approved except for a few minor items (LAV-550-68).

4.2.13.4 RCS Quantity Gaging Section - Giannini

Negotiations were completed with Giannini Controls. Results of the negotiation have been submitted to NASA for approval.

4.2.14 Reliability Assessment

TMC

Reliability Assessment was prepared for the S/M engine proposed Qualification Design and presented to NAA Reliability with Grumman representatives in attendance.

4.2.15 Failure Reporting and Corrective Action

To date Grumman has received a total of seven failure reports from Marquardt. The first report #329-001 was dated 11-9-63. This report was followed by three others dated 11-14-63, 11-21-63 and 12-12-63, all on the same part, the oxidizer valve. The next failure occurred on 2-14-64 in the combustion chamber, this was followed by a thrust chamber failure on 2-28-64. All of the above

Additional copper shavings were also found in the oxidizer instrumentation line.

The condition was corrected by installing a filter in the instrumentation line and by replacing the copper tubing with stainless steel tubing.

No. 329-002

Bench tests of failed valve indicated a dead short in the manual coil caused by a rupture of the insulation tape.

The problem was corrected by the application of a second layer of tape with staggered ends overlapping the ends of the first layer. In addition, surveillance was improved over tape application process to assure a uniform flat wrap and adequate overlap.

No. 329-004

Leakage was detected in the oxidizer valve feeding one of the vertically mounted engines. The trouble was traced to a ruptured omni-seal at the base of the valve, malformed seal flange, damaged poppet seat and ruptured teflon seal. The cause of damage was attributed to random boiling of residual fuel in dribble volume (from previous run) resulting in fuel transient into oxidizer passages.

The following corrective action was taken:

1. Delete seal level testing of vertical engine.
2. Install blind thermocouples in injection head near fuel passages for monitoring representative temperatures.
3. Instruct test facility personnel to use extreme care in the application of drilube compound to propellant system fittings.
4. Installation of compatibile filter element at the "Y" junction in the propellant manifolds.

2. Combustion Chamber Failure Analysis and Related Corrective Action

Several failure reports received from TMC reveal operating and handling problems with the combustion chambers as a result of the extremely brittle material

4.3 Guidance and Control

4.3.1 General

As indicated in previous reports, the Guidance and Control function of the LEM vehicle is so dependent on the proper operation of the Navigation and Guidance subsystem and the Stabilization and Control subsystem, that for reliability analysis purposes, they will be amalgamated in this report and all future reports. The reliability effort and proposed future effort of both GAEC and its subcontractors (as they apply to various contract end items (CEI) and to the over-all subsystem) will be outlined and discussed within this G&C framework.

In general, the GAEC Reliability effort, in the G&C subsystem, has been concerned with the following tasks:

- Preparation of Failure Mode and Effect Analysis on the discrete units of the subsystem.
- Continued review of vendor documentation.
- Continued participation in vendor negotiations and review of vendor proposals.
- Provide reliability inputs to performance specifications and vendor requirements which have not as yet been subcontracted.
- Participation in special studies and reliability analysis on subsystem equipment.
- Provide direction and assistance to vendors on reliability problems.

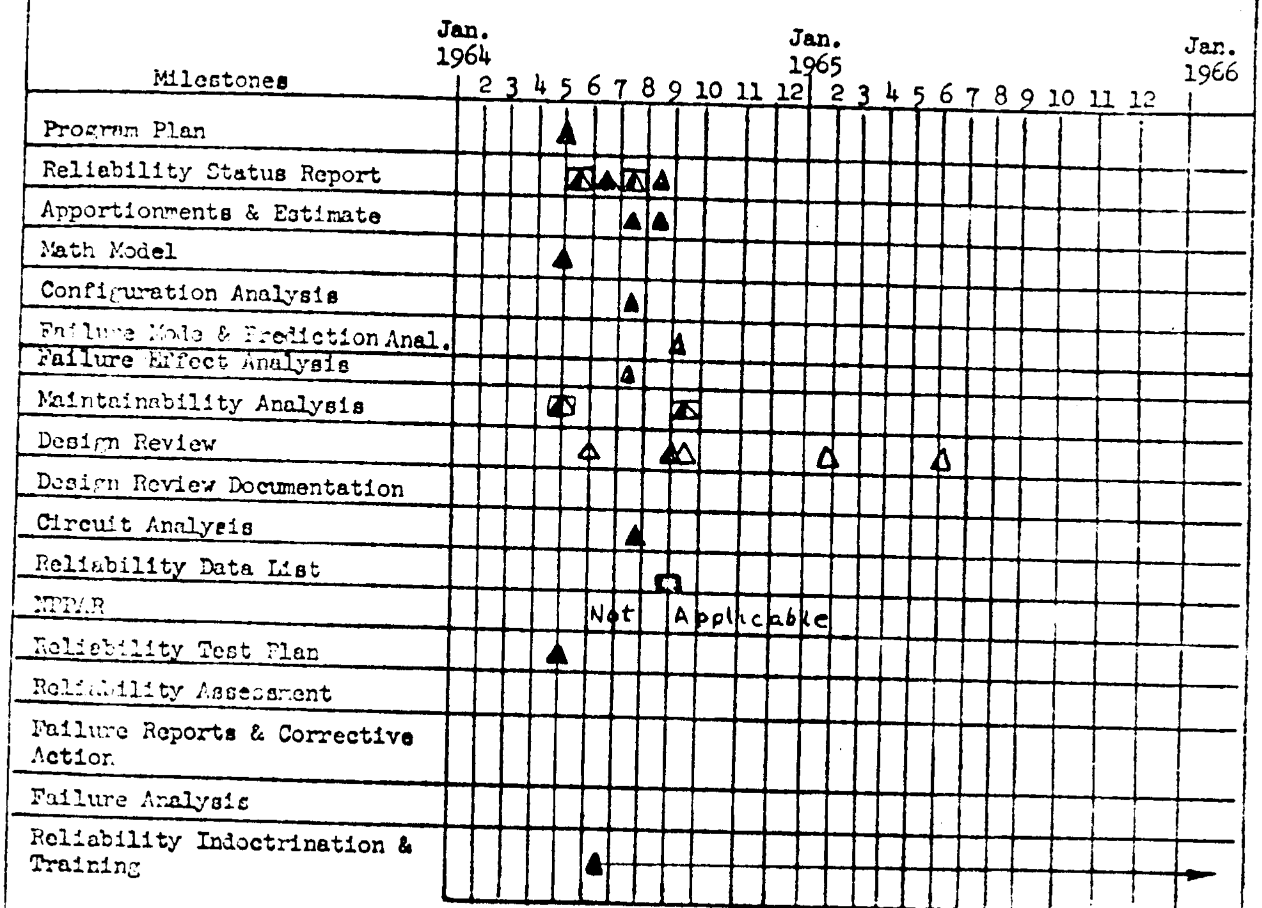
4.3.1.1 Subcontractor Status and Milestones

All equipments, in the G&C section, that have purchase orders assigned to them, will have a subcontractor status and milestone chart (following tables), delineating the work accomplished to date and when future work will be performed. All equipments, which do not have a purchase order assigned, will obviously not have a subcontractor status chart.

SUBCONTRACTOR STATUS AND MILESTONES

Subcontractor KEARFOTT
Spec. No. LSP 300-11A
Vendor Requirement
Document No.
Purchase Order No. 2-24465

Equipment RATE GYRO ASSEMBLY
Date JAN. 29, 1964
Date
Date MARCH 24, 1964



Due
Received
Accepted

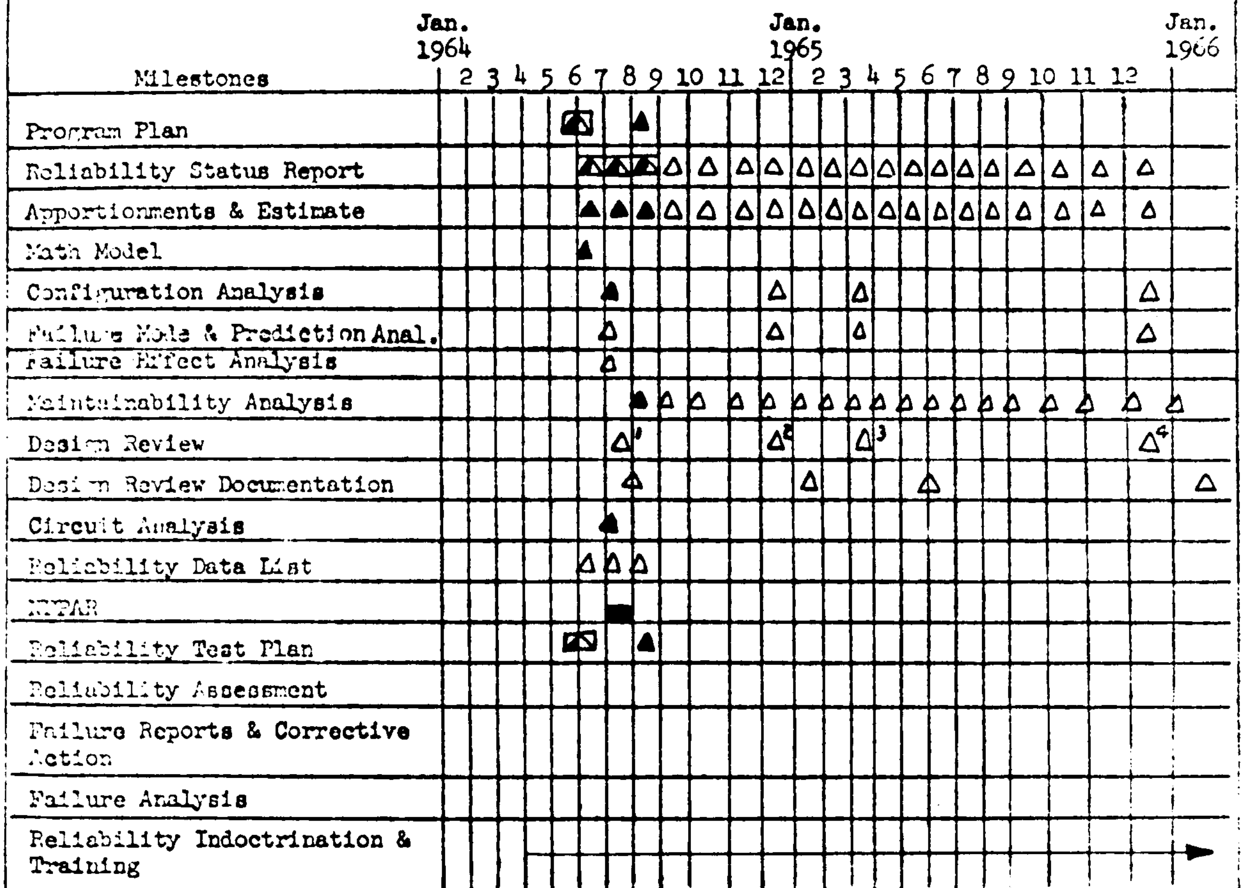
Unacceptable - Minor Exceptions
Rejected - Major Revision

4.3.1.1.4

SUBCONTRACTOR STATUS AND MILESTONES

Subcontractor RCA
Spec. No. LSP 300-14A
Vendor Requirement
Document No.
Purchase Order No. 2-24470

Equipment ATCA
Date APRIL 6, 1964
Date
Date APRIL 29, 1964



Due △
Received
Accepted ▲
Unacceptable - Minor Exceptions
Rejected - Major Revision

4.3.2.1 Summary of Effort For Period (continued)

l. Provided inputs to performance specifications.

m. Configuration analysis of different input circuits of the PCA.

n. Reviewed reliability data on contract end item (Tape Reader).

o. Assisted in the development of the LEM Mission Programmer (LMP) and the Digital Autopilot configurations.

p. Provided an input to GAEC's Program Coupler Assembly proposal; reliability section and reliability manpower estimate and distribution.

q. Reviewed the G&C portion of the Prelaunch Checkout Plan (LPL-610-3).

r. Attended monthly GAEC/MIT IL/NASA G&N Checkout Working Group meetings.

s. Effort in areas of checkout philosophy, concepts, planning and procedures.

4.3.2.2 Projected Effort For Next Period

The major tasks for the next quarterly report period consist of:

a. Evaluation of interim and final design configuration.

b. Participation in the preparation and review of performance specifications and vendor requirements.

c. Review of vendor documentation.

d. The continuation of a failure mode and effect analysis on those assemblies which have completed the initial conceptual design phase.

e. Continue updating of the unit reliabilities estimate as more empirical data on failure rates, etc. become available.

f. Participation in equipment design reviews.

g. Liaison with vendors and the resolution of certain problems in their design, documentation and/or application.

TABLE 4.3.2

Reliability Apportionments and Estimates

Equipment	Apportioned	Estimated
Attitude Indicator	0.9999 ea.	0.999747
V Indicator	0.9999	0.999657
Thrust to Weight Ratio Indicator	0.998042	0.999506
Program Reader Assembly	0.999	0.997682
Program Coupler Assembly	0.995	0.994527
Control Panel Assembly (switching)	} 0.9999	0.999703 } 0.99958
Engine Sequencer		0.999877 }
Attitude & Translation Control Assembly	0.9985	0.998739
Descent Engine Control Assembly	0.9999816	0.9998528
Gimbal Drive Assembly	0.9999184	0.99998867
Rate Gyro Assembly	0.999 ea.	0.998950
Attitude Controller	0.999 ea.	0.999673
Translation Controller	0.999 ea.	0.999702
Abort Sensor Assembly	0.9991	0.996684
Abort Electronic Assy.	0.9994	0.99809
Rendezvous Radar	} 0.999326	0.999591 } 0.999265
Transponder		0.999674 }
Landing Radar	0.999541	0.999687
Inertial Measurement Unit	0.998090	0.99914
LEM Guidance Computer	0.998090	0.99768
Power Servo Assembly	} 0.998615	0.99928 } 0.99825
Coupling Display Units (5)		0.99897 }
Alignment Optical Telescope	0.999952	0.99997

4.3.4.1 Rendezvous Radar/Transponder and Landing Radar

The model, for the LEM mounted Rendezvous Radar and the CSM mounted Transponder, is basically a serial configuration with redundant antenna gyros for the powered descent phases. Failure of a single unit would mean loss of the radar functions. After touchdown, CSM radar can be used as a first tier backup. The Landing Radar is a serial model up to the hover phase, but after this phase, its display data and the data sent to the inertial units are essentially in parallel. However, failure of either data source may still require an astronauts decision to abort. With this possibility in mind, the mathematical model for Landing Radar is considered a series combination.

4.3.4.2 Control Electronics System

In the CES section, the ATCA mathematical model shows that the pulse ratio modulators and solenoid drivers are in parallel with respect to X translation, Y rotation and Z rotation. Other modes have the elements in series. The use of the ATCA logic gates, depends upon failure of 1 of the 4 pulse ratio modulators or 1 of the 4 solenoid drivers and astronaut sensing and action. Failure detection of the rate gyro choice circuit also depends on the failure of a rate gyro. The reliability model for the DECA, considered all units, except the failure detection logic, in series. The use of the logic depends upon a failure of the gimbal on the descent engine. All other equipment in the CES, have been considered serial models by either the vendor or by GAEC, where no vendor has been subcontracted.

4.3.4.3 Abort Guidance System

Since at the writing of this report there has not been a purchase order signed for the AGS, the GAEC model which was used for the reliability estimate is a serial arrangement. That is, the ASA, AEA and also constituent assemblies thereof are serially configured.

4.3.4.4 LEM Mission Programmer

The mathematical model for the LMP is still in a preliminary state. This preliminary model is presented in LMO-550-331, which will be updated in the future.

4.3.5.3 LEM Mission Programmer

An analysis on the PCA, which is part of the LEM Mission Programmer, was performed (LMO-550-404), comparing two decoding circuits and comparing three different input circuits. It was determined that an integrated decoding network and a comparison type input circuit had particular reliability advantages. Effort was also spent, reviewing reliability data on punched tape readers for space application and it was concluded that a tape reader can be employed.

4.3.6 Failure Mode and Effect Analysis

The Failure Mode and Effect Analysis has been initiated or continued on all equipments, which have completed the initial design phase of development. The FMEA will highlight design and operational weaknesses, inherent in the particular equipment design, and will provide an improved understanding of the equipments mechanization and operation.

4.3.6.1 Rendezvous Radar/Transponder and Landing Radar

RCA's FMEA on the Rendezvous Radar/Transponder was reviewed. It was apparent that RCA required further clarification, as to the proper preparation of the FMEA and this was accomplished at a GAEC/RCA Reliability meeting. A GAEC FMEA has been completed on a complete functional loss basis. In addition, degradation type failures were also examined and effort will continue in this area. A preliminary copy, of Ryan's FMEA on the Landing Radar, was reviewed and it appears to be amenable to the GAEC effort.

4.3.6.2 Control Electronics System

In the CES area, the Rate Gyro FMEA by the vendor has been initiated. The vendor has classified the major functional components and most likely modes of failures. The most likely failures are flex lead breakage and spin motor winding failure.

4.3.6.3 Primary Navigation and Guidance System

No effort on FMEA on the PNGS was performed. However, GAEC has received and reviewed MIT's Failure Mode and Effect Analysis on their Block I system. This, according to MIT, is being updated for Block II and many of the cited failure modes will be equally applicable for the Block II effort.

4.3.8.2 Control Electronics System

The ATCA Monthly Progress Reports and Support Manual were reviewed and RCA was requested to include detail as to failure detection, isolation and repair procedures in future reports. All Kearfott documentation on the RGA was reviewed and pertinent comments and clarifications were transmitted to the subcontractor. Maintainability personnel attended the GAEC/Kearfott Experimental Unit Design Review meeting.

4.3.8.3 Abort Guidance System

Maintainability inputs were supplied for the AGS specifications and general agreement was reached on all maintainability issues except the rebiasing of gyro drift rate. Para. 3.3.2 of LSP-300-37, requires rebiasing after a 30 day period, which will impose serious constraints on the checkout program because removal of the ASA from the vehicle is required. The proposed vendor was requested to examine the possibility of designing, so that rebiasing could be accomplished with the ASA installed in the vehicle.

4.3.8.4 Primary Navigation and Guidance System

The maintainability effort,with regard to the PNGS, centered on checkout concepts and test planning. Maintainability has attended N&G Checkout Working Group meetings at which maintainability has advocated integrated end to end testing. MIT and GAEC disagree on the integrated end to end tests to be employed; MIT favors the use of test programs within the LGC while GAEC favors external inertial stimuli supplied to the LGC,where the actual flight program could be exercised.

4.3.9 Design Reviews

Design Reviews were held on some of the equipments under contract and will be held on these and other equipment as the program evolves.

4.3.10.2 Control Electronics System (continued)

- Placing a fuse in the line between the Elapsed Time Indicator and the Gyro excitation.
- The use of an alternate connector proposed to replace Hughes connector. This was disapproved because GAEC will recommend an improved Hughes connector.
- Change resistor from 1.5 to 2.0 watts with aluminum heat sink, to obtain higher safety margin.
- Change certain zener diodes from 250 mw to 400 mw rating.

The torquer circuit input resistor is rated for 275°C while actual operating temperature is 93.3°C. The temperature is believed to be excessive and the vendor has been directed to reduce this part surface temperature.

4.3.11 Reliability Data List

The Reliability Data List have been reviewed by the Reliability Parts Group and the Subsystem Group, for compliance with GAEC approved parts philosophy, application requirements.

4.3.11.1 Rendezvous Radar/Transponder and Landing Radar

GAEC has received three RDL's on the radars and these were found to be acceptable with certain exceptions:

- MC80V capacitors manufactured by Aerovox was disapproved.
- Semiconductor devices considered non-preferred parts requiring NPPAR's.
- Items listed, that have not been approved by GAEC, although other parts have been approved.
- Parts that appear on list, which have not been submitted for approval by GAEC.

For further details see LAV-550-72.

4.3.12.2 Control Electronics System

There have been 5 NPPAR's in the CES section on the ATCA and the status is as follows:

- Approved - 1
- Disapproved - 3
- Pending - 1

4.3.12.3 Abort Guidance System

No NPPAR's have been submitted on the AGS.

4.3.12.4 LEM Mission Programmer

No NPPAR's have been submitted on the LMP.

4.3.12.5 Primary Navigation and Guidance System

No NPPAR's are required on the GFE MIT supplied on the PNGS.

4.3.13 Reliability Test Program

The following is a brief discussion of vendor test plans and philosophy,to be used in the development of his particular equipment. These tests include Reliability Boundary Tests, Design Feasibility Tests, and Qualification Tests, etc. as stipulated by the respective purchase orders.

4.3.13.1 Rendezvous Radar/Transponder and Landing Radar

Feasibility tests on the Rendezvous Radar were completed during the report period,for the following components of the experimental model; frequency multiplier, divide by eight divider, oscillator and oven, x 48 multiplier, modulator subassembly, x 33 multiplier, ICW range converts. Feasibility tests on the Landing Radar were

4.3.15 Failure Reporting and Corrective Action

Failure reports are required from the vendor on a monthly basis, on all failures that occur during testing and production. Each report should indicate the failure and appropriate corrective action taken. All failures will be recorded on tape as part of the integrated LEM Computer Program.

4.3.15.1 Rendezvous Radar/Transponder and Landing Radar

Two failure reports from RCA on the rendezvous radar were received. The first failure consisted of a broken solder connection, on a coil supplied by Delevan Electronic Corporation. Investigation revealed, that the wire had broken between the tie off point and the winding. As a result, a 100% visual inspection on soldering is now required. The other failure concerned a shorted transistor supplied by Motorola. Some deficiencies which have existed in RCA's report have been brough to their attention by GAEC and RCA has stated these will be corrected.

4.3.16 Failure Analysis

Failure analysis will be performed on all failures, which require such analysis, to determine the nature and cause of the failure.

4.3.16.1 Rendezvous Radar/Transponder and Landing Radar

In the radar area, a failure analysis was performed on the shorted transistor mentioned in Para. 4.3.15.1. The analysis showed that the unit was subjected to an electrical over-stress during testing and the test procedures will be changed, where necessary, to eliminate any future problems.

4.3.17 Reliability Training and Indoctrination

Training programs in reliability have been conducted at the vendor to acquaint design engineers with the reliability aspects of the system.

4.4 Communications Subsystem

4.4.1 General

During this quarter, the Communications Subsystem Reliability effort was devoted to the continued analysis of those essential subsystem reliability requirements detailed in the GAEC Reliability Program Plan.

4.4.1.1 Subcontractor Status and Milestones

Table 4.4.1.1 is the subcontractor status and milestone chart for RCA, the major subcontractor. Below, an equipment/contractor summary is presented for the remaining equipment.

TABLE 4.4.1.1.1

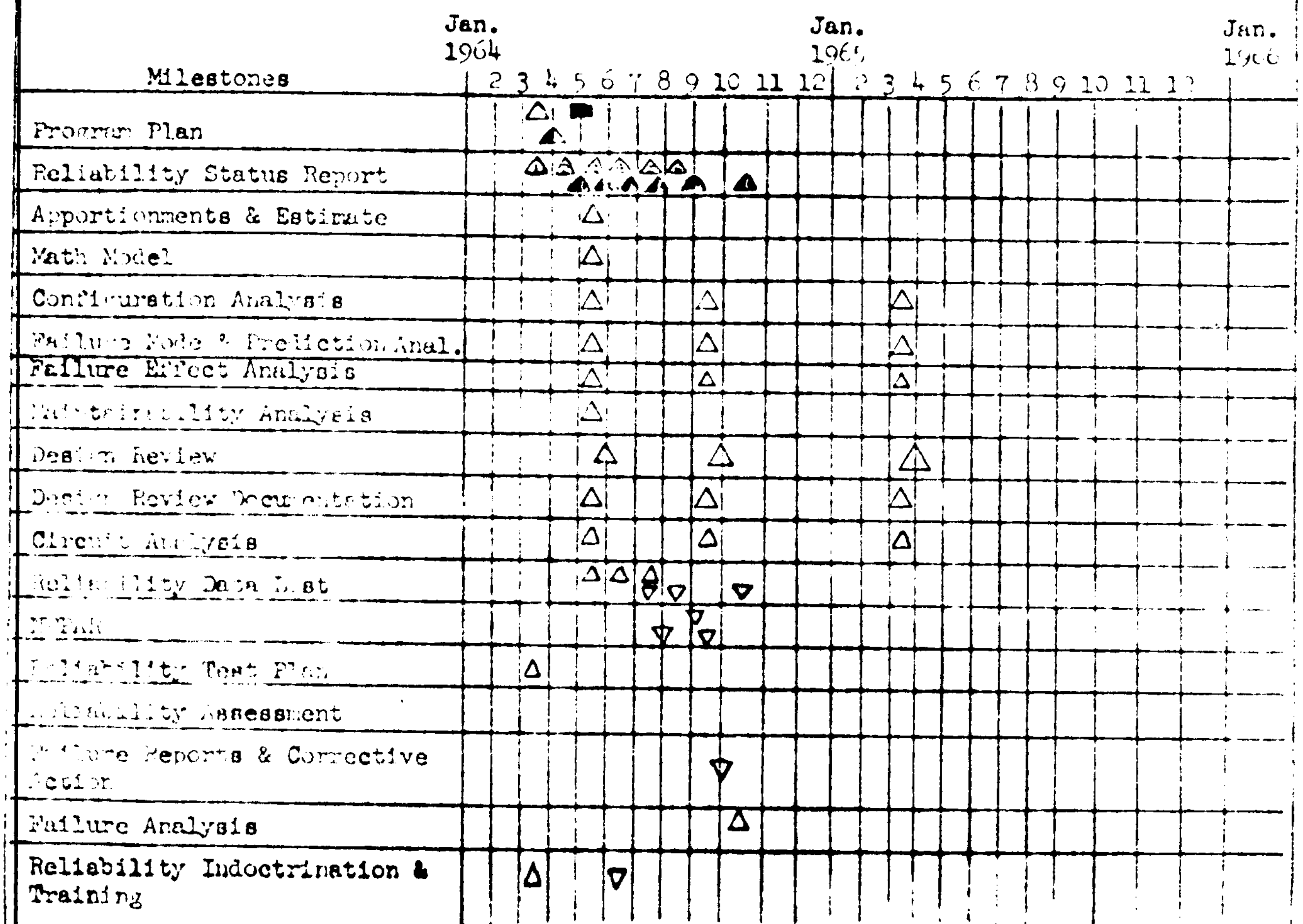
Equipment/Contractor Summary

Equipment	Contractor	P.O. No.	Spec. No.
VHF Transceiver	RCA	2-24463-C	LSP-380-2
VHF Omni Antenna	GAEC	Not Applicable	LSP-380-4
VHF Lunar Stay Antenna	GAEC	Not Applicable	LSP-380-5
VHF Coax Antenna Select. Switch	Quantatron	Pending	LSP-380-7A
VHF Diplexer	Rantec	2-24475	LSP-380-3A
Pre-Modulation Processor	RCA/Collins	2-24463-C	LSP-380-2
Audio Center Assembly	RCA/Collins	2-24463-C	LSP-380-2
Personal Communication System	NASA	GFE	Not Applicable
S-Band Transceiver	RCA/ Motorola	2-24463-C	LSP-380-2
S-Band Power Amplifier	RCA/ Raytheon	2-24463-C	LSP-380-2

TABLE 4.4.1.1
SUBCONTRACTOR STATUS AND MILESTONES

Subcontractor R.C.A.
Spec. No. LSP 380-2
Vendor Requirement
Document No. LVR 380-1
Purchase Order No. 2-24463-C

Equipment COMMUNICATION
Date FEB. 7, 1964
Date AUG. 5, 1963
Date FEB. 13, 1964



Due △
Received ; Partially ▽
Accepted ▲
Unacceptable - Minor Exceptions
Rejected - Major Revision

4.4.2.2 Projected Effort For Next Period

During the next quarterly report period, the Communications Subsystem Reliability effort is expected to center about the following areas of activity.

a. The Failure Mode and Effects Analysis should be completed in accordance with the requirements of the Reliability Plan.

b. It is expected that considerable reliability effort will be expended during this period in compiling Reliability Block Diagrams for each communications link. In this regard, link and modal reliability analysis for each diagram will be initiated.

c. As expected a significant portion of the reliability effort will be devoted to coordination with the many Communications Subsystem vendors. Documentation including specifications reports, proposals, quarterlies, will be reviewed and disseminated. Technical coordination meetings, design reviews, conceptual presentations and demonstrations are expected to be numerous. Effort in the area of circuit analysis design review and configuration analysis will begin together with monitoring and evaluating components.

d. The Communication Antennas Reliability Plan should be finalized and released. This plan covers the S-Band inflight antennas, the VHF inflight antennas, and the VHF lunar stay antenna.

e. The maintainability effort for the next period will be in the continuation of the study to establish the adequacy of the present test points and measurements for fault isolation, failure analysis and operational readiness and to make recommendations for improvement where required. The vendor maintainability effort will be closely monitored. Inputs to specifications, review of documents and reports with comments and recommendations as required, will be provided.

4.4.3 Reliability Apportionments and Estimates

During the period, the initial apportionment of the reliability goals were established (LEM Monthly Progress Report No. LMR-(P)-4100-5, dated 31 July 1964, RCA, Burlington, Mass.) by the vendor (RCA) for the VHF Set, 4.4.5 Configuration Analysis (continued)

a. A circuit analysis and study (Raytheon, Space and Information Systems Division, Memo No. LMP-64-28, dated 5 June 1964, L. Pauplis, "Configuration Analysis LEM Amplifier Design") was conducted to determine the need for a dual section LC filter in the output circuit to reduce the output signal moise content. The study concluded that circuit design has allowed the use of a single section LC filter. This decrease in critical parts will increase reliability.

b. Studies (Raytheon, Space and Information Systems Division, Memo No. LMP-64-28, dated 5 June 1964, L. Pauplis, "Configuration Analysis LEM Amplifier Design") and (Raytheon, Space and Information Systems Division, Memo No. 64-JFP/AS-1, dated 5 June 1964, J. F. Perkins, A. Sorgi, "Circuit Trade-Offs") were made on the pre-regulator to reduce its weight. Studies and tests showed that stabilization of the excitor input voltage is not required. Therefore, the excitor could be removed from the pre-regulator package. This decrease in complexity will also increase reliability.

c. A number of trade-offs (Ratheon. Space and Information Systems Division, Memo No. 64-JFP/AS-1, dated 5 June 1964, J. F. Perkins, A. Sorgi, "Circuit Trade-Offs") were made on the methods of sensing over-voltage of the power supply. Consideration of the various techniques, i.e., light transducer method, pulse width sensing, voltage divider, unijunction circuit, and current level discrimination, has resulted in the selection of the pulse width technique for sensing over-voltage because it contains a minimum number of parts, requires no high voltage divider, requires minimum power drain and performs the sensing function in the most positive manner. This adds up to a considerable reliability increase.

d. A study (Ratheon, Space and Information Systems Division, Memo No. 64-JFP/AS-1, dated 5 June 1964, J. F. Perkins, A. Sorgi, "Circuit Trade-Offs") of the various recycling modes of operation for the power supply timing circuitry is in progress, evaluating a trade-off between flexibility, complexity, size, system considerations and power requirements. GAEC is still awaiting results of this study.

4.4.5 Configuration Analysis (continued)

Considerable effort has been expended during this period by GAEC and vendor Reliability in order to evaluate the new requirements (GAEC Letter No. LLR-170-835, dated 3 August 1964, Grumman P.O. No. 2-24463-C; also GAEC Letter No. LLR-170-751, dated 14 July 1964) for performance and redundancy. The RCA proposal covering the new requirements delineates the improved reliability of the LEM Mission which is accomplished by an additional VHF data transceiver, a low power VHF transmitter, an S-Band receiver, PM Modulator and power amplifier. The signal processing section provides additional switching and redundancy paths providing alternate paths of communication. Implementation of the new configurations will provide a significant increase in the operational modes permitting a wide choice of primary back-up and alternate means of communication.

4.4.6 Failure Mode and Effect Analysis

During this report quarter, the Communications Subsystem Failure Mode and Effect Analysis (FMEA) was begun. This analysis (Pending GAEC Memo, dated October 1964, J. Mc Gowan, J. Adells, "Communications Subsystem Failure Mode and Effect Analysis") was performed on the S-Band section, the VHF section, the Pre-Modulation Processor, the Audio Center, the Personal Communications System and the Cabin Intercom. System. The purpose of this analysis by GAEC at the systems level was to provide an insight and understanding of the communications system, so that vendor FMEA's when submitted could be thoroughly and adequately evaluated. GAEC is devoting particular attention to the methods of detecting failures, to the compensating provisions and to the effects on the subsystem, the LEM and the Mission. This will provide an understanding as to the consequences of a particular failure and the corrective action that can be accomplished by the astronaut.

A Preliminary Failure Mode and Effect Analysis was submitted (LEM Monthly Progress Report No. LMR-(P)-4100-5, dated 31 July 1964, RCA, Burlington, Mass.) on the Raytheon S-Band power amplifier by RCA. Reliability has reviewed this effort and has taken exception to a number of items; e.g., the definition of compensating provisions and also the causes of failures. GAEC feels that all significant failures have not been considered in sufficient detail.

4.4.8.2 Vendor Effort

This reporting period has been limited to a preliminary analysis of the S-Band power amplifier and to the conceptual packaging design of the Electronic Replaceable Assemblies. The analysis of the power amplifier gave only cursory consideration to the overall effort and covered only the trade-off study for replacement. RCA has been informed that a more detailed study is required.

During this period RCA presented maintainability concepts that are generally acceptable for performing an analysis and are in line with the concepts of GAEC. The concepts presented are general in nature and the vendor has been informed that the concepts presented are not to be construed to preclude the requirements called out in the design specifications and vendor requirements.

4.4.9 Design Reviews and Technical Meetings

4.4.9.1 Design Reviews

The following Communication Subsystem Design Reviews were attended by GAEC personnel and the following items were considered:

a. A VHF Transceiver Conceptual Design Review (RCA Memo No. LDR-C-4270-2, dated 31 July 1964 (pending approval) W. Carlino, "Design Review Report: VHF Transceiver Conceptual Review", and GAEC AVO No. LAV-381-66, dated 10 September 1964, E. Griffin, N. Darch, "VHF Transceiver Conceptual Design Freeze") was held at RCA, Camden, New Jersey on July 27-28, 1964. At this meeting, the functional description and conceptual design approach were discussed and approved. GAEC granted a design freeze pending resolution of a number of action items, many of which involved reliability aspects. The following items were discussed which affected the Communication Subsystem Reliability.

   1. Reliability has requested data to substantiate: 1) the temperature stability of the varactor diode and its associated circuitry, 2) the failure rate calculation for the 2N3375 transistor and 3) use of tantalum capacitors for filtering.

4.4.9.2 Technical Meetings (continued)

a. Monthly Technical Meeting (RCA Letter No. LCC-(P)-4140-31, dated 24 September 1964, enclosing "Minutes of Monthly Technical Meeting RCA/Raytheon, dated 9 September 1964") GAEC Reliability had indicated that the redundancy considerations for the Power Amplifier (PA) will increase the problem in determining proper operations of the PA. Raytheon will submit a report justifying the use of coaxitube instead of flexible cable. Raytheon stated that based on their limited test program, an isolator is not needed between the tubes in a redundant configuration. GAEC Reliability had requested life test data and will evaluate the need for a life requirement on the tube.

b. Monthly Technical Meeting (Meeting Minutes, Monthly Technical Meeting RCA/Collins, dated 10 September 1964). At this meeting, it was agreed that Reliability data will be furnished in accordance with the contract, regardless of common usage aspects. Reliability Data Lists, Apportionments, Reliability Block Diagrams, Maintainability Studies and Failure Reports will be included. GAEC Reliability requested configuration analyses on the power regulators, and additional reliability data concerning loss of voice and data.

c. Monthly Technical Meeting (Minutes of Monthly Technical Meeting RCA/Motorola, dated 15 September 1964). The Reliability diagram for the redundancy configurations were discussed in detail, including failure rates and probability of success. A configuration comparison with respect to reliability, power, complexity, weight and the number of controls was discussed in detail. The method of part selection and approval, the reliability considerations on part derating, failure modes and corrective action were all discussed.

d. Technical Meeting GAEC/RCA.Dalmo Victor (GAEC Memo No. LMO-550-403, dated 23 July 1964, J. Arleth "Additional Reliability Agreement of RCA/Dalmo Victor/GAEC Steerable Antenna Meeting of 26 August 1964") GAEC Reliability has requested that Dalmo Victor provide reliability data:

4.4.10 Circuit Analysis (continued)

GAEC Reliability has also reviewed a preliminary circuit schematic and analysis (Raytheon, Missile Systems Division, Bedford Laboratories, Memo No. RME-441, dated 8 June 1964, H. Lane, C. Jahnke, D. Fradette, "LEM Reliability Data List, Circuit Analysis and Reliability Estimates") for the S-Band power amplifier. An analysis of this circuit was made recognizing the preliminary nature of the circuits. The associated reliability data list was reviewed. Both the preliminary circuit analysis and associated data list were found generally acceptable although some insulation parameters are under close scrutiny in the high voltage circuitry. Exceptions and comments to this analysis were made known to RCA and Raytheon at the design review.

4.4.11 Reliability Data Lists

During this report period, a preliminary Reliability Data List (LEM VHF Transceiver Reliability Data List No. RDL-C-4270-1, dated 30 June 1964, RCA, Camden, New Jersey.) was submitted to GAEC Reliability Control on the VHF transceiver breadboard model. While it is understood that non-approved parts are acceptable only on the breadboard RCA was notified and cautioned against the use of such parts on the deliverable equipments. Some components were electrically stressed above the recommended .3 limit. The GAEC Reliability comments on this RDL were coordinated with RCA at the ensuing design review (RCA Memo No. LDR-C-4270-2, dated 31 July 1964 (pending approval) W. Carlino, "Design Review Report: VHF Transceiver Conceptual Review" and GAEC AVO No. LAV-381-66, dated 10 September 1964, E. Griffin, N. Darch, "VHF Transceiver Conceptual Design Freeze")

4.4.12 Non Preferred Parts Approval Request (NPPAR) Status

As required by the contract, RCA must forward NPPAR reports to GAEC as evidence of the adequacy of non-standard parts in both performance and reliability for specific applications. Forty seven NPPAR reports have been received on communication parts to date. Seventeen were approved, two were disapproved, two had approval withheld, and the other twenty six are pending while objections are being resolved.

4.4.16 Failure Analysis

Since no Communication Subsystem failures have been reported to date, neither vendor no GAEC Failure Analyses were required or performed during this quarter.

4.4.17 Reliability Training and Indoctrination

A Reliability Training and Indoctrination program was completed by RCA for the Camden integration personnel. This program included eight reliability training sessions and four USN reliability training films.

Additional training and indoctrination sessions are planned which will more specifically deal with LEM Reliability particulars.(GAEC Memo No. LMO-550-370, dated 23 July 1964, R. Komuves, J. Arleth "Reliability Comments on RCA First Quarterly Report")

TABLE 4.5.1.2.

SUBCONTRACTOR STATUS
& MILESTONES

Subcontractor HAMILTON STANDARD
Spec. No. LSP 330-2A
Vendor Requirement
Document No.
Purchase Order No. 2-18828-C

Equipment ENVIRONMENTAL CONTROL
Date SEPT. 15, 1964
Date
Date Aug 9, 1963

Milestones	1963	Jan. 1964	4	7	10	Jan. 1965	4	7	9	10	Jan. 1966
Program Plan		Submitted Sept 25, 63 [illegible]									
Reliability Status Report	▲	△	▲	▲	▲	△	△	△		△	△
Apportionments & Estimate	▲	△	▲	▲	▲	△	△	△		△	△
Math Model	▲	△	▲	▲	▲	△	△	△		△	△
Configuration Analysis	▲	△	▲	▲	▲	△	△	△		△	△
Failure Mode & Prediction Anal.	▲	△	▲	▲	▲	△	△	△		△	△
Failure Effect Analysis	▲	△	▲	▲	▲	△	△	△		△	△
Maintainability Analysis	▲	△	▲	▲	▲	△	△	△		△	△
Design Review		NOT APPLICABLE									
Design Review Documentation		NOT APPLICABLE									
Circuit Analysis		NOT APPLICABLE									
Reliability Data List	▲	△									
[illegible]		NOT APPLICABLE									
Reliability Test Plan	▲										
Reliability Assessment	▲	▲	▲	▲	▲	△	△	△		△	△
Failure Reports & Corrective Action									△		
Failure Analysis									△		
Reliability Indoctrination & Training		▲									
RELIABILITY TEST PLAN							△				

Due △ Unacceptable - Minor Exceptions
Received Rejected - Major Revision
Accepted ▲

FORM G328 REV 1 8-64
Contract No. NAS 9-1100
Primary No. 760

REPORT LPR-550-7
DATE November 1, 1964

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
CODE 26512

4.5.2.1.3 ECS Redundant Cooling Loop - Equipment Recommendations

As a result of a series of studies a tabulation of the equipment to be cooled by the ECS redundant cooling loop in the event of a primary cooling loop failure was prepared and recommendations made. LMO-540-365 provides the documentation for the following equipment selection for the redundant loop.

1. Rate Gyro Assembly (RGA) (2)
2. Abort Sensor Assembly (ASA)
3. Abort Electronic Assembly (AEA)
4. Flight Director Attitude Indicator (FDAI)
5. Rendezvous Radar Transponder
6. Rendezvous Radar Electronics
7. Attitude and Translation Assembly (ATCA)
8. VHF
9. Electrical Control Assembly (ECA) (3)
10. Signal Conditioners Electronic Assembly (SCEA)
11. Pulse Code Modulation Timing Equipment Assembly (PCMTEA)
12. Inverter
13. S-Band

4.5.2.1.4 Proposed Test Program For Brushless DC Motors

As reported during the subsequent reporting period GAEC had recommended to NASA that reliability test program for Brushless DC Motors be established. On 10 August 1964 a meeting was held at Windsor Locks, Connecticut, with GAEC and NASA. As a result of this meeting LLR-330-16 outlined a revised test program for a reliability assessment of the light energized, electrically commutated motors. LTE-550-55 provided additional test background information to NASA on the current test program for Brushless DC Motors.

To date no action has been taken by NASA on the recommended test program.

4.5.3 Reliability Apportionments and Estimates

4.5.3.1 Apportionment of Estimate of ECS Subsystem

Present Estimate		Apportionment	
Mission Success	Crew Safety	Mission Success	Crew Safety
.994056	.999088	.999446	.99982

4.5.3.1.1 Equipment Breakdown of ECS Components

Item	Contractor	Apportionment		
ECS Components	HSD	R	.999500	.995811
* CO_2 Sensor	P-E	MTBF	100,000 hrs.	No Contract Awarded
* Cold Plates	-	R	.999995	No Contract Awarded

For discussion and explanation of difference between apportionment and estimate see Paragraph 4.5.6.

4.5.4 Reliability Math Model

During this period Hamilton Standard has calculated the reliability of the latest ECS configuration. Figure 4.5.1 shows the latest ECS configuration. The results are as follows:

RELIABILITY STATUS

	Failure Per 10^6 Mission	
	Mission Success	Crew Safety
Reliability Goals	500	100
Configuration as of 30 April 1964	10,058	1,913
Configuration as of 25 August 1964	4,189	139

* These items are/will be under separate contract from the rest of ECS system but are included in reliability estimate and apportionment of Paragraph 4.5.3.1.

ENVIRONMENTAL CONTROL
RELIABILITY SCHEMATIC FOR
CONFIGURATION STUDY
REF HSD SVSK 50742P.

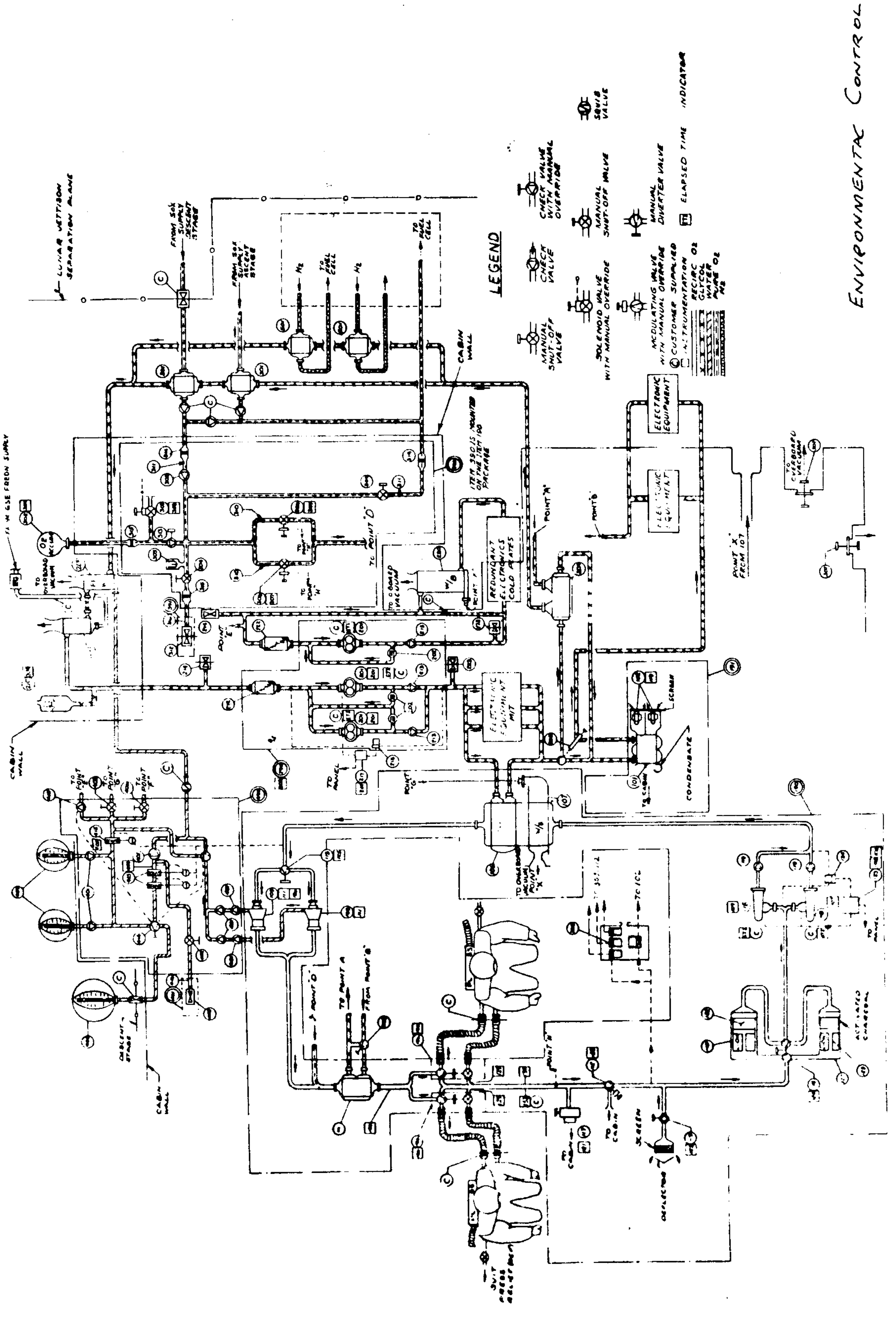


Fig. 4.5.1

4.5.7 Failure Mode Prediction Analysis

Hamilton Standard continued to submit preliminary component and assembly failure mode predictions during this quarter. At present, these are best estimates and will be updated as development testing progresses.* As the predictions are firmed up and approved by Reliability, the comments will be included in succeeding reports.

4.5.8 Maintainability Analysis

4.5.8.1 GAEC Effort

The fundamental characteristics of the ECS design are being reviewed to determine its particular set of maintainability advantages and limitations.

Under investigation during this period was the Atmosphere Revitalization Section of the ECS. The following recommendations were offered and are of particular interest in providing operational readiness.

a. Revision to ECS LIOH canister design to incorporate a simple and effective cover design which utilizes a leverage type handle to move cover and cartridge in one motion.

b. Provide positive locking arrangement for cover.

4.5.8.2 Vendor Effort

The vendor effort in the design of the ECS has provided maintainability consideration such as; accessibility, maintenance procedures at various levels, field maintenance conditions to determine what level of maintenance can be considered and recommendations to provide field support supplies.

* The critical environments under which the sixty odd items being developed by Hamilton Standard are predicted to fail vary extensively from item to item (e.g., vibration temperature and pressure for heat exchangers, vibration and collapse pressure loading for the Suit Circuit Porous Plate Evaporator; comtamination plugging or seal failures due to deterioration under 100 per cent O_2 or Glycol for check valves, etc.).

4.5.12 NPPAR Statistics

Not applicable to ECS.

4.5.13 Reliability Test Program

4.5.13.1 Hamilton Standard Division

Hamilton Standard is presently scheduled to submit the Reliability Assurance Detail Test Plan by May 1965. In the meantime Reliability Test personnel are reviewing and critiquing other "Design Verification Detail Test Plan" in order to assure that sufficient testing is accomplished prior to the formal "Reliability Assurance Tests."

An initial test plan was submitted for the Suit Temperature Control Valve (Item No. 208) for technical evaluation and formal concurrence. Resolution is required on the test format and the remaining items are to be submitted for GAEC approval.

4.5.13.2 Brushless DC Motors

See Paragraph 4.5.1.2 for summary and status of proposed test program.

4.5.13.3 CO_2 Partial Pressure Sensor

See Paragraph 4.5.1.2.2 for summary and status of test analyses.

4.5.13.4 Cold Plate Section

Reliability Assurance Test inputs are being incorporated in the single and double passage cold plate specification.

4.6 Electrical Power Subsystem

4.6.1 General

The EPS is made up of two majorsystems, the Power Generation System (PGS) and the Power Distribution System (PDS). The PGS is further along in development and the procurement of hardware. Pratt and Whitney is the vendor for the FCA and AiResearch is the vendor for the cryogenic storage tankage. These are the only vendors currently under contract in the EPS area.

4.6.1.1 Subcontractor Status and Milestones

Tables 4.6.1.1 and 4.6.1.2 are the Status and Milestone charts for Pratt and Whitney and AiResearch.

4.6.2 Subsystem Summary

4.6.2.1 Summary of Effort For Period

During this report period GAEC EPS Reliability participated in the following effort:

1. Revised PGS reliability estimate for mission based on single fuel cell failure abort criterion.
2. Analyzed and set requirements for the Electrical Control Assembly.
3. Configuration Analyses were performed in the following areas:
   a. Weight-Reliability trade-off studies.
   b. Descent Supercritical tank pressurization system redundancy.
   c. Fuel Cell Assembly Study.
   d. Electrical Control Assembly for FCA.
   e. Redundant Bus and Feeder Systems.
4. EPS System FMEA and review of vendor FMEA efforts.
5. Review of preliminary failure mode prediction analysis by AiResearch.
6. Maintainability analysis of FCA mounting.

TABLE 4.6.1.4 (CONT.)

SUBCONTRACTOR STATUS AND MILESTONES

Subcontractor PRATT & WHITNEY
Spec. No. LSP 390-2A
Vendor Requirement
Document No. LVR 390-2
Purchase Order No. 2-18845-C

Equipment FUEL CELL
Date AUG. 23, 1963
Date APR. 29, 1963
Date NOV. 18, 1963

Milestones	Jan. 1965	2	3	4	5	6	7	8	9	10	11	12	Jan. 1966	2	3	4	5	6	7	8	9	10	11	12	Jan. 1967
Program Plan																									
Reliability Status Report																									
Apportionments & Estimate																									
Math Model																									
Configuration Analysis																									
Failure Mode & Prediction Anal.		△																							
Failure Effect Analysis																									
Maintainability Analysis																									→
Design Review			△																						
Design Review Documentation		△																							
Circuit Analysis								Not		Applicable															
Reliability Data List																									
NPPAR								Not		Applicable															
Reliability Test Plan						△																			
Reliability Assessment																									
Failure Reports & Corrective Action	△																								→
Failure Analysis	△																								→
Reliability Indoctrination & Training																									

Due △
Received ▲
Accepted ▲

Unacceptable - Minor Exceptions
Rejected - Major Revision

4.6.2.1 Summary of Effort for Period (continued)

7. Design reviews took place in the following areas:
   a. Cryogenic tankage conceptual design review
   b. General purpose inverter electronic packaging review
   c. Level 3 electrical schematic review

8. Reliability data lists received from vendors were reviewed.

9. Review of preliminary reliability assurance test plan from PWA and AiResearch.

10. Reviewed and analyzed failure reports of PWA.

11. Reviewed proposals and entered negotiations for PGS component vendors and the General Purpose Inverter as well as the circular connectors.

4.6.2.2 Projected Effort for Next Period

In the forthcoming report, effort will be continued in many of the areas listed in Para. 4.6.2.1. Design reviews and associated tasks will take place as equipment procurement and development proceeds. LED-550-30, which shows the math model of the PGS and ECS concomittent functions, will be updated and reissued to incorporate the new fuel cell abort criteria.

4.6.3 Reliability Apportionments and Estimates

	Apportionments	Estimates
System Breakdown		
Electrical Power Subsystem	.99815	
Power Generation System	.9984	.93875
Power Distribution System	.999762	
Equipment Breakdown		
Fuel Cell Assembly (3 required)	.990	.974
Cryogenic Tank (5 required)	.9997	

4.6.3 Reliability Apportionments and Estimates (continued)

The ECA is in the process of being defined and consequently has no estimate.

Yardney has indicated that they will meet their apportionment of .9998 but have not as yet signed a P.O. with GAEC.

The inverter P.O. has not been signed with Hamilton Standard, consequently no estimate has been received from them.

4.6.4 Reliability Mathematical Model

The mathematical model of the EPS consists of two major systems in series, i.e., the PGS in series with the PGS. The PGS consists of three fuel cells and one auxiliary battery in series for mission success, which is in turn in series with the cryogenic reactant storage and feed system. LED-550-30, dated 15 May 1964 shows the concomittent functions of PGS and the Environmental Control System. A slight revision is necessary to update these mission functions to make it conform to TWX-PL2-T8-4/64-377, dated 17 August 1964. The PDS consists of (a) the logic necessary to parallel the fuel cells and (b) the power feeders that distribute the power to the power consuming equipment. GAEC Reliability is in the process of evaluating several schemes of redundant and non-redundant feeder systems and will report its findings in the next Quarterly Report.

PWA's math model shows all component parts in series. The math model can be found in their Preliminary Reliability Report PWA 2411, dated 15 January 1964. AiResearch has submitted a math model which is incorrect due to AR's not having a complete understanding of the LEM mission. This has since been clarified with AiReserach.

4.6.5 Configuration Analysis

During the last report period GAEC reliability continued to update the weight reliability report which was originally issued on 18 March 1964 as LED-550-24. The EPS configurations that were studied were the one fuel cell assembly failure abort criterion as per TWX-PL2-T8-4/64-377, dated 17 August 1964. The LED-550-30 math model was modified in order to calculate the current estimate which appears in Para. 4.6.3 for the Power Generation System.

4.6.6 Failure Mode and Effect Analysis (continued)

is being paid to "Failure Detection Methods" so that the crew can be alerted to the failure promptly so that remedial action may be taken. Care is also exercised to determine that all the compensating provisions are documented so that full understanding of the consequences may be known.

AiResearch Manufacturing Company submitted an FMEA contained within a Design Report for Tank Assembly-Cryogenic Storage and Supply, Electrical Power Subsystem for the LEM, dated 28 August 1964 numbered SS-3168. This effort was as complete a job as could be expected at this time by AiResearch. At the reliability meeting, held at AiResearch during the Conceptual Design Review, A.R. indicated that an updating is in process and a more complete effort will be forthcoming as equipment requirements become more firm.

The stratification of Cryogenic fluid in the reactant tanks was considered to be one of the major problems confronting the Engineers at AiResearch Company and GAEC.

Stratification is a physical phenonenom of crygoenic fluid in a zero-G. environment during stand by, where there is no flow or motion of the cryogenic fluid.

This can cause errors in the temperature measurements, in gaging measurements, and may cause improper heater functioning. Errors may occur when measuring the fluid mass during stratified conditions due to the fact that the capacitance probe measures incorrectly during this condition if the stratification layers are not perpendicular to the probe.

AiResearch suggested, in the corrective action column of their FMEA, the use of fans to agitate the fluids, in order to minimize the problem of stratification. However, this could lead to other reliability problems, especially in extreme low temperature environments.

Upon investigation and evaluation of the relief valves to be incorporated in the design of the three ascent tanks, the FMEA indicated that the potential impact of failure would be catastrophic. Redesign of the least reliable components of the valve are under consideration at this time in an effort to improve the over-all reliability of the valve and the tankage system.

4.6.8 Maintainability Analysis (continued)

Maintainability participated in studies to investigate the possibility of relocating the Fuel Cell's Electrical Control Assembly to the Cold Plate Area in the Aft Equipment Bay.

4.6.9 Design Review

During this report period many informal design reviews as well as one formal design review took place.

AiResearch submitted their Design Report, SS-3168 dated 28 August 1964, for the Conceptual Design Review held at AiResearch, on 14-18 September 1964, for the Cryogenic Storage and Supply Tankage. The meeting minutes, LVM-5050-0118 dated 22 September 1964, detail the general and parallel sessions that took place and the action items that ensued. LMO-550-431, dated 9 October 1964, discussed the reliability aspects of the design review. In this LMO, 9 reliability problem areas were delineated.

As part of the General Purpose Inverter negotiations with Hamilton Standard GAEC Reliability took an active part in the electronic packaging design review for this ERA.

A continuing effort for EPS reliability has been the review of Level 3 Electrical Wiring Schematics. The review has been twofold. First, the power consuming equipment is reviewed with the cognizant subsystem reliability engineer, to ascertain if the proper redundancy philosophy assumed for a particular equipment, is followed through electrically on the Level 3. Second, the Level 3 is reviewed so as to guarantee that the best inherent reliability is incorporated in the design. During the last report period the Level 3 Schematics that were reviewed are:

LDW-310-60000 RCS
LDW-270-60000 Propulsion
LDW-330-6000 ECS

Those Level 3 Schematics currently under review are:

LDW-350-6000 Display and Control GASTA
LDW-390-60000 Electrical Power Generator
LDW-320-60000 Electro Explosives

4.6.13 Reliability Test Program

A preliminary FCA Reliability Assurance Test Plan was forwarded to Grumman by PWA for comments prior to their submittal of the formal plan (a Type I document). Upon completion of the Reliability review, a coordination meeting between Grumman and PWA will be set up to resolve any remaining areas in question. One problem under study is the limiting of start-up and shut-down cycles of the FCA during the tests. The presently anticipated cycle capacity of 14 should not be exceeded during the Mission Simulation phase of the tests. The significant Design Feasibility tests conducted at PWA are summarized in Table 4.6.13.

A preliminary Tank Assembly Reliability Assurance Test Plan SS-3173 dated 17 July 1964, was received from AiResearch. The proposed test contained a number of deviations, such as improper levels of environments, additional accelerated tests, etc., which are to be resolved in a forthcoming coordination meeting.

Negotiations for the Reliability Assurance tests with Fairchild-Hiller for the Cryogenic Interstage Quick Disconnect were completed. Negotiations with Parker Aircraft for the Cryogenic Solenoid Valve were also completed.

Proposals for the Cryogenic Fill and Vent Valves were evaluated for compliance with the Reliability Assurance requirements of the respective detail specifications.

4.6.14 Reliability Assessment

No effort for this period since there has been no testing.

4.6.15 Failure Reporting and Corrective Action

During this report period failure reports were received from PWA on the FCA. No failure reports as yet have been submitted by AiResearch on the cryogenic tankage.

TABLE 4.6.13 (continued)

ITEM	TESTS & RESULTS
Reactor Subassembly Multi-cell Stacks	Performance and Endurance Tests on 15-cell stacks continued on Rigs # 27117 (builds 4 thru 9L) and 27123 (builds 2E thru 5), with frequent occurrances of failure. The major modes of failure were KOH leakage and O_2 line and/or inlet plugging. For example, of 82 failures, these modes accounted for approximately 60. Times to failure varied anywhere from 5 to 100 hours. It has been noted that some cells in a multi-cell stack experience a performance loss in a relatively short time. This loss is suspected to be associated with oxygen starvation. Investigation is in process.
Single Cells (bolted-flange)	Performance and Endurance Tests 1. Previous H_2 screen-sinter separation has ceased to be a problem area through improved design and fabrication techniques. 2. KOH leakage is now the main problem and is serious. Steps are being taken to eliminate (e.g., low-creep teflon on order to replace the organic seal at the H_2 top flange.) 3. H_2 electrode and O_2 electrode plugging failures deminishing due to geometric fixes and use of nickel foil on the electrodes. The majority of present plugging is apparently a result of KOH leakage through the sintered electrodes. 4. Internal (dendrite) shorting is now being manifested as single cells begin to run in excess of 100 hours. Magnitude of problem not known at present. Tests underway to evaluate.

TABLE 4.6.13 (continued)

ITEM	TEST & RESULTS
Reactant Control Subassembly (cont.)	
Pressure Regulators	Sine Vibration Tests of B/M regulators (soft mount simulation) completed. Serious resonances in the critical axis of all regulators caused venting. Analysis of tests in process.
Solenoid Valves O_2 Purge Valve	Vendor redesigned as a result of the previous over-limit continuous purge flows. Vibration tests resulted in changed flow rate. Study in process.
H_2 & O_2 Shut-Off Valve	Performance Tests - passed at room and elevated temperatures. However endurance tests of the H_2 shut-off valve showed indications of partial loss in valve flow capability and flow deficiencies due to temperature effects. Tests to evaluate teflon seat distortion at elevated temperatures in progress. Both H_2 and O_2 shut-off valves passed vibration tests.
N_2 Supply Valve	Endurance tested at room temperature - leakage of O-ring seal. Vendor advised. Vibration Tests - failed due to contamination.
Transducers	Vibration and cycling tests at elevated temperatures (+250 to +500°F) in process.
Structures & Miscellaneous	
Support Structure	Statically tested. Results satisfactory. Vibration tested in 3 major axes. Results satisfactory.

4.6.15 Failure Reporting and Corrective Action (continued)

The PWA failure reporting program has been progressing satisfactorily. PWA is engaged in feasibility types tests primarily performed on single cells. These single cells are mainly of the bolted flange variety, and as such are non-flyable hardware. To date 172 failures have been submitted and 5 failure reports have open items where no failure analysis or corrective action was performed. These open failures date back to April, May and June, and close-out statements have been requested of the vendor. Since these failures were the result of feasibility type tests on non-flyable hardware, reporting of these failures is not a specific requirements of NASA. A brief summary of the tests and failures are given in Table 4.6.13.

AiResearch has submitted their failure reporting and corrective action forms as part of the Cryogenic Storage and Supply Tankage program plan, SS-3090 Rev. 1, dated 22 August 1964. These forms have been approved by GAEC. As yet no failures have been reported, since only a very limited amount of feasibility testing has taken place.

In the future the Monthly Failure Summary Report will be placed on tape by the LEM Reliability Computer Program.

4.6.16 Failure Analysis

Failure analysis efforts are three fold: (1) Those analyses performed by vendors on vendor failures, (2) GAEC coordination of vendor failure analysis effort, (3) Analysis performed by GAEC on GAEC failures. During this report period failure analysis was performed on all failures in the feasibility test program of the FCA by PWA, with the exception of the five open items mentioned in Para. 4.6.15.

As part of PWA's failure analysis program every effort was made to analyze the cause of each failure. By monitoring the results of these analyses, it became

4.7 Structures and Mechanical Design

4.7.1 General

Significant progress has been made, in the past quarter to assure that the reliability of the actual hardware will equal or exceed the apportioned values. A breakdown of this progress in the various applicable categories will be found in the following subsections.

4.7.1.1 Subcontractor Status and Milestones

Present subcontractor status and milestones reached to date are presented in Tables 4.7.1.1 and 4.7.1.2 for the ascent stage propellant tankage (Aerojet-General) and for the descent stage (Allison).

4.7.2 Subsystem Summary

4.7.2.1 Summary of Effort For This Period

a. A configuration analysis for the ascent stage propulsion tanks was started.

b. A configuration analysis for the descent stage propulsion tanks was started.

c. A weight-reliability study was performed on the electrical umbilical of the ascent descent stage separation joint.

d. Work is in progress on a new separation joint configuration for the stage separation system.

e. Work is continuing on the water-line disconnect for the stage separation system.

f. Failure effect analyses are currently in progress on the structure, landing gear, stage separation system, hatches and other mechanical design systems.

g. Failure effect analyses on the lunar descent and ascent propulsion tanks have been made by the vendors.

h. Maintainability requirements for the descent propulsion tanks were reviewed.

Table 4.7.1.2

SUBCONTRACTOR STATUS AND MILESTONES

Subcontractor ALLISON
Spec. No. LSP 280-4
Vendor Requirement
Document No. LVR 280-4
Purchase Order No. 2-24456-C

Equipment DESCENT STAGE PROP. TANK
Date DEC. 3, 1963

Date DEC. 3, 1963
Date DEC. 3, 1963

Milestones	Jan. 1964	2	3	4	5	6	7	8	9	10	11	12	Jan. 1965	2	3	4	5	6	7	8	9	10	11	12	Jan. 1966
Program Plan	⊠				▲																				
Reliability Progress Report		▲			▲			▲			△			△			△								
Apportionments & Estimate		▲			▲			▲			△			△			△								
Math Model									Not Applicable																
Configuration Analysis		⊠									△		△												
Failure Mode & Prediction Anal.		▲									△		△												
Failure Effect Analysis		▲			▲			▲			△			△			△								
Maintainability Analysis		▲			▲			▲			△			△			△								
Design Review		▲									△		△												
Design Review Documentation			⊠									△		△											
Circuit Analysis									Not Applicable																
Reliability Data List				△				△			△			△			△								
NPPAR																									
Reliability Test Plan											△														
Reliability Assessment																									
Failure Reports & Corrective Action																									→
Failure Analysis																									
Reliability Indoctrination & Training																									→

Due △
Received ◭
Accepted ▲

Unacceptable - Minor Exceptions ⊠
Rejected - Major Revision ■

[redacted]

TABLE 4.7.3

Reliability Apportionments and Estimates

Subsystem	Reliability			
	Apportioned		Estimated	
	Mission Success	Crew Safety	Mission Success	Crew Safety
Landing Gear	.999900	.999995	Not Available	Not Available
Ascent Propellant Tanks	.999998	.999998	Not Available	Not Available
Descent Propellant Tanks	.999995	.999995	Not Available	Not Available
Ascent-Descent Stage Separation Systems *	.999994	.999994	.999999*	.999999*

* Electrical and Fluid Disconnect System not included.

[redacted]

4.7.6 Failure Mode and Effect Analysis

a. Vendor Effort

Aerojet-General, the vendor of Ascent Stage Propellant Tanks, submitted a failure mode and effect analysis, report #1-4081-01-7.9 dated 12 August 1964. The report listed the possible failures that could occur, the causes if determinable, and the effect of the failures on the tanks. The report was carefully reviewed and accepted.

The Allison Division, G.M.C., the vendor of the Descent Stage Propellant Tanks submitted a failure effect analysis, report # 3767 dated 8 February 1964. This document was also reviewed and accepted.

b. GAEC Effort

During this period effort has continued toward completion of a Failure Mode and Effect Analysis, designed to highlight any design and operational weaknesses that might be present and the effect of any failures that might occur on the mission completion and safety of the astronauts. A further objective will be to determine what can be done to eliminate certain failures or to reduce their criticality.

4.7.7 Failure Mode Prediction Analysis

a. Aerojet-General submitted a subject analysis, report # 1-4081-7.10 dated 12 August 1964. The report listed the failures that could occur, their probability and their criticality. The report was reviewed and accepted.

b. Allison Division, G.M.C. submitted a subject analysis, report #EDR-3767 Table 6, dated February 8, 1964. The document was reviewed but was found to be non-acceptable. The submitted report did not indicate the anticipated modes of failure during the required tests.

4.7.9 Design Review (continued)

a. Vendor Items (continued)

Of particular interest to GAEC was the statistical analysis of forging strength data. The study was conducted to establish the lower strength limits that might be expected from three different forging processes which could be used in forging the tank shells.

b. GAEC Items

During this reporting period there has been no formal design reviews involving Grumman Reliability personnel on Grumman designed Structural items. In the past, reliability studies have been performed on such structural items as types of blind rivets, window seal-mount, etc. The structural analysis group performs a reliability type function, and acts as a check for the structural designer.

4.7.10 Circuit Analysis

Not applicable.

4.7.11 Reliability Data Lists

No effort for this period.

4.7.12 NPPAR Status

Not applicable.

4.7.13 Reliability Test Program

Ascent Stage Propellant Tank - Aerojet-General submitted a General Test Plan during this quarter. Reliability Control's comments on the subject plan are in progress.

4.8 Crew Provisions Subsystem

4.8.1 General

4.8.1.1 Subcontractor Status and Milestones

To date no subcontractors have been selected, thus there are no status and milestones to report on during this quarter.

4.8.2 Subsystem Summary

4.8.2.1 Summary of Effort During This Period

a. A configuration analysis was started to determine the optimum design of a combination portable/dome light.

b. Effort on the Failure Mode and Effect Analysis continued.

c. Study on the need for a crew support and restraint system is continuing.

d. Various astronaut ascent/descent devices (ladders, hoists, ropes, etc.) have been studied to try to determine the optimum system for transporting men and material from the LEM capsule to the lunar surface and return.

e. The LEM M-5 mockup is being studied to determine possible hazards and failure modes.

4.8.2.2 Projected Effort for Next Quarter

a. Continue failure mode and effect analysis.

b. Continue monitoring drawings for design feasibility and reliability.

c. Continue liaison with design engineers on all systems and components.

4.8.3 Reliability Apportionment and Estimate

Numerical apportionments not applicable.

4.8.7 Failure Mode Prediction Analysis

No analyses were submitted during this quarter for the crew provisions subsystem since the procurement specifications have not been released.

4.8.8 Maintainability Analysis

a. Grumman Effort

During this reporting period there has been no maintainability analysis on the Crew Provisions Subsystem.

b. Vendor Effort

No suppliers have been established for this subsystem and therefore, there has been no effort in supplier maintainability analyses.

4.8.9 Design Review

There have been no formal design reviews during this reporting period. For the subsystem design reviews are a continuing informal process between the design engineers, reliability, maintainability, producibility, testing, etc., and each discipline is continually aware of the current status of the design.

During these informal reviews, reliability is careful to direct the attention of the designers to existing and potential hazards, alternate design changes, which will increase reliability and safety, and changes dictated by past experience.

4.8.10 Circuit Analysis

Not applicable.

4.8.11 Reliability Data Lists

Since no subcontracts have been let on the Crew Provisions Systems, there are no reliability data lists to report.

4.8.12 NPPAR

No effort in this period since no subcontracts have been let.

4.9 Instrumentation Subsystem

4.9.1 General

4.9.1.1 Subcontractor Status and Milestones

Table 4.9.1.1-1 lists the equipment in Instrumentation S/S where information about P.O. Specification and Contractor is given.

TABLE 4.9.1.1-1

Equipment	P.O.	Specs. & LVR's	Contractor
PCMTEA	2-18848-C	LSP-360-2A	Radiation
SEA	None	In Preparation	None
SCEA	None	In Preparation	None
C&WEA	None	LSP-360-8	Arma
DSEA	None	LSP-360-12	None *

* In process of procurement.

Radiation's status concerning reliability effects are given in Table 4.9.1.1-2.

4.9.2 Subsystem Summary

4.9.2.1 Summary of Effort For Period

Review and commented on Monthly Progress Reports, Design Report No. 2, PCM Reliability Estimates and Failure Effect Analysis submitted Radiation.

Reliability studies were performed on PCM design. The study considered redundancy of the Programmer, High Level Analog Gates and Digital Multiplexer; these subassemblies are below the level of reliability necessary for the PCM to meet it's requirements of .9975. Details and results of the study are presented in LMO-550-418.

A system level FMEA was completed by GAEC reliability for the PCM based on the component level FMEA submitted by Radiation. Reliability documents and parts evaluation lists were reviewed and comments have been submitted.

4.9.2.1 Summary of Effort For Period (continued)

The calculated reliability of TEA, based mainly on MIL-HDBK-217 failure rates, shows that the present reliability is acceptable. A system-level FMEA was completed by GAEC reliability for the TEA based on the component-level FMEA submitted by Elgin. Reliability documents and parts evaluation lists were reviewed. All parts and specifications have been approved with the following exceptions; Specification 7000003 Part 7020003 Revision "B".

A study was initiated to find a solution to the problem imposed on PCM reliability requirements by NASA's directive AC 564-191/6-17-64. Results of this study will be presented in the near future.

Preliminary efforts were completed to determine the number of transducers used, their complexity, and their classification as to crew safety or mission success. Crew safety transducers are defined as those transducers which process crew safety parameters; mission success transducers process mission success parameters. Reliability numbers were apportioned for each transducer based on results of the above efforts. The LEM-10 measurement list was used as a basis for the apportionment effort. Details of the results are presented in LED-550-16A, dated September 10, 1964.

Reliability evaluations were performed on transducer configurations presented by the subsystem for comparison and design selection purposes.

Reliability inputs to transducer specifications were prepared and submitted to the Instrumentation Subsystem group.

Certain Signal Conditioning Units (SCU) proposed designs were evaluated with respect to reliability and then compared with the apportioned reliability. This study was undertaken to reveal the possible problems that could be encountered in SCU designs and what techniques might be employed to meet the required reliability.

The apportioned SCU reliability used in the comparison was based on estimated SCU complexity and number used. Details concerning SCU development are presented in LED-550-16A, dated September 10, 1964.

4.9.2.2 Projected Effort For Next Period (continued)

d. Study design requirements versus proposed configurations.

e. Re-examine transducer apportionments in light of latest information.

f. Review transducer Design Control Specifications, Vendor Requirements and provide reliability input where necessary.

g. Attend GAEC Vendor and Subsystem interface meetings.

h. Review LEM-10 measurement list and follow-up Instrumentation Subsystem activities in this area.

These efforts will enable a more detailed study of transducers and perhaps relieve the reliability requirements.

Similar efforts will be expended in SCU area as in transducer area. It is evident at this time that great strides will have to be taken in both SCU and transducer areas in order to meet the required reliability.

The PCM and TEA design progress will be followed and reliability report documents and parts evaluation lists will be reviewed. RDL's will also be reviewed and compared to data presented in schematics. At present the PCMTEA is being re-evaluated to determine whether it is mission essential or non-mission essential equipment. If the equipment is re-classified as mission essential, the reliability requirements will be higher and re-newed studies will be performed to investigate areas of PCMTEA design which could be improved. The effort for the next period will consist of continuing the analysis to establish operational readiness and to monitor, coordinate and direct the vendors effort as may be required. In addition, effort will continue in providing inputs to specifications and reports.

4.9.3 Reliability Apportionments and Estimates

Table 4.9.3 gives the apportioned reliability and estimated reliability (for those equipments under contract) for assemblies in Instrumentations Subsystem.

As can be seen from Table 4.9.3, the PCM estimated reliability is below the required level. The following areas were

4.9.4 Reliability Mathematical Model (continued)

The TEA has redundancy in the oscillator section, comparator circuits (majority logic), and Quad Amplifier. The oscillator section reliability was calculated simply by utilizing the reliability as $1-Q_1 Q_2$ where Q_1 and Q_2 are the two alternate path unreliabilities. The comparator circuits and quad amplifier, however, consist of somewhat more complicated redundancy and required a math model which was generated from the results of the TEA FMEA (generated by Elgin). The math models are based on alternate path concept.

4.9.5 Configuration Analysis

A configuration analysis was performed on PCM (LMO-550-418 as mentioned in Para. 4.9.2) to determine degree of reliability improvement by strengthening certain weak links in PCM design. A summary of this study follows:

Due to the present reliability status of the PCM (0.9935)*, compared to the goal (.9975), the weak links of the PCM design were examined and a preliminary redundancy scheme was considered.

In LSP-360-2A it is clearly stated that redundancy could be used in order to improve the reliability of the PCMTEA. In spite of this agreement, the vendor did not show strong effort in this direction due to weight constraints.

1. Before it is too late, weak links of the PCM design should be pointed out, and indicate the possible areas where redundancy can be applied and the resulting reliability improvement. The weak links are the Programmer, High Level Analog Gates and the Digital Multiplexer.
2. A preliminary study was completed on the basis of the present available technical information; the weak links were merely placed actively redundant in blocks. This was done to avoid the effects resulting from insertion of the switching means, when stand-by redundancy is considered.

* Radiation's reliability estimate.

4.9.8 Maintainability Analysis

4.9.8.1 GAEC Effort

A high percentage of the Instrumentation Subsystem equipments are in the specification and/or vendor requirement stage, or are in the early development stage therefore limiting the scope of maintainability analysis.

A preliminary analysis of the PCMTEA was initiated during this period. The anticipated complexities of the packaging were critiqued and recommendations were made for avoiding some of the pitfalls. Test point and measurement data was reviewed for the purpose of determining operational readiness.

4.9.8.2 Vendors Effort

The vendor maintainability analysis effort for this period has been restricted to the PCMTEA. A high percentage of the other equipments are in the specification or early design stages and sufficient data is not available to warrant an analysis at this time.

The vendor has completed a maintainability analysis of his design to date and at last reporting was in the final typing stage. The vendor's analysis is expected to be available during the next reporting period and more conclusive results concerning specifics will be reported.

4.9.8.3 Problem Areas

1. PCMTEA

    a. Use of soldered interconnections as test points for fault isolation.

        GAEC has recommended that the vendor study alternate means for making measurements available in the event that it becomes necessary to conformally coat the wiring interconnections.

    b. When the ERA case is removed and the subassemblies are fanned out for accessibility, excessive stress could possibly be placed on the subassembly interconnections thus inducing additional failures.

4.9.13 Reliability Test Program

4.9.13.1 Pulse Code Modulation and Timing Electronic Assembly (PCMTEA) Radiation, Inc.

Design feasibility testing on both the mechanical and thermal models is continuing. In turn Test Reports have been evaluated and further testing is indicated.

The Service Test Model (STM) Acceptance Test Procedure has been evaluated but approval has been withheld pending inclusion of recommendation.

Subcontractor Change Proposal No. 8 has been received from Radiation and is concurrently being evaluated in preparation for negotiations on the revised Reliability Test Program.

4.9.14 Reliability Assessment

No effort to report in this period.

4.9.15 Failure Reporting and Corrective Action

The first two failure reports have been received from Radiation, Inc. in August 1964 and referenced in our Monthly Failure Summary Report, LPR-550-112, dated September 15. Both reports occurred during development bench checkout of the Pulse Code Modulator System. One failure consisted of a shorted transistor caused by an overstress condition during a development test. The other, revealed foreign matter in the digital multiplex bit gate card assembly. Corrective actions have been enacted and both reports are closed.

These and all future failures will be recorded on tape in our LEM Reliability Program and integrated analysis will be conducted as failures are documented.

4.9.16 Failure Analysis

No effort to report in this period.

4.10 Displays and Controls Subsystem

4.10.1 General

As previously mentioned only controls and displays which are not in primary functional modes of other subsystems will be treated in this section.

4.10.1.1 Subcontractor Status and Milestones

Specification and Vendor Requirements have been generated for the majority of the devices involved in Displays and Controls Subsystem. Negotiations were held but vendors have not yet been selected. See Table 4.10.1.1.

4.10.2 Subsystem Summary

4.10.2.1 Summary of Effort for Period

A study of Displays and Controls hardware began and will continue until all the information necessary for an apportionment has been gathered.

A study of the Controls and Displays interfaces with other subsystems has begun in order to establish reliability activity in this area and avoid duplication of efforts.

The maintainability effort for this period has consisted of providing inputs and reviewing specifications, and investigating the physical locations of controls and displays for replacement and accessibilities.

4.10.2.2 Projected Effort for Next Period

1. Continue hardware study in Displays and Controls and obtain the following:
   a. Functional Block Diagrams showing major module involved in each device.
   b. Type and number of parts per module.
   c. Relative complexity for each device.
   d. Basic interface ground rules.

4.10.2.2 Project Effort For Next Period (continued)

2. Classify all devices into:
    a. Crew Safety items.
    b. Mission Success items.
3. Carryout the apportionment.
4. Provide all devices with the proper reliability input.
5. Review Design Control Specification and Vendor Requirements.
6. Follow-up Displays and Controls Subsystem efforts.

Maintainability Effort for the next period will consist of reviewing and commenting on vendor documents and reports, providing inputs to specifications, monitoring the vendors maintainability efforts, and analyzing the design of the controls and displays for fault isolation and failure analysis capabilities.

4.10.3 Reliability Apportionments and Estimates

No effort in this period.

4.10.4 Reliability Mathematical Model

As of now nothing is available, however, efforts are being made to gather the information necessary for this activity.

4.10.5 Configuration Analysis

Nothing yet is available however, existing designs are under study.

4.10.6 Failure Mode and Effect Analysis

Nothing yet is available however, existing designs are under study.

4.10.13 Reliability Test Program

No contracts awarded as yet.

4.10.14 Reliability Assessment

No effort to report at this time.

4.10.15 Failure Reporting and Corrective Action

No effort to report at this time.

4.10.16 Failure Analysis

No effort to report at this time.

4.10.17 Reliability Training and Indoctrination

No effort to report at this time.

4.11.1.1

TABLE 4.11.1.1
Equipment Status List

Crit. Class.	Part No.	Equipment Name	LSP Review	LSP Sign-Off	LVR Review	LVR Sign-Off	Vendor Evaluation	Vendor Negotiations	AMN Review & Sign-Off	Purchase Order No.	Sub-Contractor
MEE	430-54200	Unit, Gaseous O_2 Supply	X	X	X	X	X		X		
	430-54400	Unit, Cabin Leak Test	X	X	X	X	X		X		
	430-54600	Unit, Freon Supply	X	X	X				X		
	430-54700	Unit, Water Glycol Trim Control	X	X	X	X	X	X	X		
	410-64020	Controller, Prop. Load Cont. Assembly	X		N/A	N/A	N/A	N/A	X	N/A	N/A*
	430-64220	Unit, Helium Press. Dist.	X		N/A	N/A	N/A	N/A	X	N/A	N/A
	430-64420	Unit, Prop. Load Cont. Assy.	X		N/A	N/A	N/A	N/A	X	N/A	N/A
MSE	420-13750	Positioner, Cleaning	X		N/A	N/A	N/A	N/A		N/A	N/A
	410-32160	Test Sta. C-Band Transp. Maint.	X								
	430-52110	Test Stand, Thermal Perf.	X								
	430-52120	Test Bench, Gaseous Comp.	X	X	X	X	X	X		2-24488	Ham.Std.
	430-52160	Test Stand, Water Comp.	X	X	X	X	X	X		2-24488	Ham.Std.
	430-52210	Test Stand, Water Glycol Comp.	X	X	X	X	X	X		2-24488	Ham.Std.
	430-54800	Unit, Water Vapor Extract.	X								
	410-62080	Test Set, RCS Prop. Quantity Gaging	X								
	430-62100	Test Stand, He Component	X	X	X	X				2-24469	REF Dyn.
	450-62162	Transmitter, Flow Rate Turbine	X								

* In-House

4.11.1.1 (continued)

TABLE 4.11.1.1 (continued)

Equipment Status List

Crit. Class.	Part No.	Equipment Name	LSP Review	LSP Sign-Off	LVR Review	LVR Sign-Off	Vendor Evaluation	Vendor Negotiations	AMN Review & Sign-Off	Purchase Order No.	Sub-Contractor
MD/TE cont'd	430-5500	Simulator, Int.Envir. IES	X	X	X	X	X	X	X	2-24460	Bethlehem
	430-6320	Stand, Fuel Storage & Trans	X	X						2-57307	Prop.Sys. Inc.
	430-6330	Stand, Oxid.Storage & Trans	X	X						2-57307	" "
	430-6340	Cond.Unit, Substitute Fuel							X	2-57308	Budd Elect
	430-6350	Cond.Unit, Substitute Oxid.							X	2-57308	Budd Elect
	410-7500	Test Sta. PCMTEA Dev.	X								Radiation
	410-7600	Test Sta. C&WEA Dev.	X	X	X	X	X	X			Arma
	410-7700	Test Sta. DSEA Dev.	X	X	X	X					
	410-7900	Console, Instrumentation	X		X						
	430-8120	Supercritical & LO_2 Dev. Bench	X	X	X	X	X	X	X		APCO
	430-8130	Supercritical & LH_2 Dev. Bench	X	X	X	X	X	X			APCO
	430-8140	Test Bench, Fuel Cell Gas Dev.	X	X	X	X	X	X		2-24473	FEDCO
	430-8170	Leak Detector, He - H_2	X	X	X				X		
	410-8371	Ripple Cont. Module	X								
	450-9200	Sta.LEM Data Reduction	X	X	X	X			X		
	400-9923	Transducer,Diff.Press. Unidirect.	X								
	440-41001	External Visual Display Equipment	X	X	X	X	X	X		2-24459-C	Farrand
	440-43100	LEM Mission Simulator	X	X	X	X	X	X		2-24481-C	Link

4.11.2.3 Vendor Proposal Evaluation and Negotiations

The vendor proposals evaluated and the vendor negotiations conducted during this report period are indicated in the "Equipment Status List" Table 4.11.1.1. Proposals were evaluated for compliance with the specified reliability requirements, presentation, and the organizational capability of the vendor. In addition, prior to contract award, reliability participated in vendor negotiations to clarify any misinterpretations or exceptions taken by the vendor in the proposal. Further surveillance of several vendors under contract has been conducted, to assure their compliance with the reliability design requirements.

4.11.2.4 Failure Mode and Effect Analysis

During this report period, the format to be used for Failure Mode and Effect Analysis (FMEA) was finalized and is shown in Figure 4.11.1.1. This format follows that currently used for analysis of the flight hardware as closely as possible and will be included in all future procurement data packages (LVR's).

The first GSE item on which a FMEA was performed using this format was the Internal Environmental Simulator (IES) 430-5500B. This analysis was subsequently issued in report form (See Reference (d). Certain design changes were recommended as a result of this analysis (See Reference e) and were forwarded to the design group for their review and comment.

Additional FMEA's are currently in progress on 410-64018, Controller, Helium Distribution Unit and 410-64020, Controller, Propellant Loading Control Assembly both of which are in-house MEE.

4.11.2.5 HSTE vs ACE Evaluation

An attempt to compare House Test Equipment (HSTE) against ACE-S/C (including carry-on equipment) was performed. It was hoped that a numerical reliability figure could be determined in order to show the relative merits of one compared to the other. This reliability input was to be added to the overall evaluation along with other analyses of capability, cost, and availability. The overall object was to aid LEM Project in presenting their requirements for HSTE to NASA.

4.11.2.5 HSTE vs ACE Evaluation (continued)

The reliability effort was not finalized for the following reasons:

1. The HSTE during this period was not defined to the level where reliability could make a valid comparison.
2. Reliability predictions (MTBF) were available for ACE-S/C, however, there was no information as to the method used in obtaining these figures.

In general, the analysis was based on the complexity of each type of equipment. It was estimated that there would be (35) standard racks of HSTE compared to (150) racks for ACE-S/C. In addition, at least 50% of the HSTE was required to support ACE-S/C. Another assumption was that the HSTE design would follow as a minimum the design criteria used for ACE-S/C.

On the basis of the above information it was concluded that the HSTE would command a higher reliability than ACE-S/C.

4.11.2.6 Common-Usage GSE

A workable reliability program plan acceptable to GAEC and NAA for common-usage GSE evolved during this report period. The program will provide for the transmittal of NAA reliability information on the (31) items of common-usage GSE to GAEC for their information and review. GAEC in turn will furnish NAA certain data for use in their reliability assessment program. Some of the information already received from NAA has been utilized in the mission essential GSE studies of Para. 4.11.2.1.

4.11.2.7 Parts

During this reporting period considerable effort has been expended in the parts control area. A formalization of the electrical parts selection and application program has been achieved, and LEM-GSE design engineers have been apprised of the procedures necessary to conform with the requirements of NPC-250-1 for part selection and application. To facilitate the approval of GSE components, Reference (f) was issued. This document informs cognizant personnel of the

4.12 Electronic Packaging

4.12.1 General

4.12.1.1 Major Effort For The Period

The largest reliability effort during this period has continued to be in the area of technical monitoring and assistance. This has been accomplished through:

a. Review of and comment on documentation, e.g., proposals, packaging studies, reports, memos and specifications.

b. Attendance at vendor packaging presentations, technical coordination meetings and subcontractor negotiations.

4.12.1.2 Technical Monitoring and Assistance Areas

Effort has been expended on a number of subsystems, which are discussed individually in the following sections.

4.12.1.2.1 LEM Propulsion Subsystem

This system uses solenoid-operated valves for controlling helium flow to propulsion. A change in the method of wiring to these valves was requested by the Electrical Power Subsystems engineering group. This change is discussed in Paragraph 4.10.1.2.4.3 below.

4.12.1.2.2 Guidance and Control Subsystems

4.12.1.2.2.1 Attitude and Translation Control Assembly (ATCA)

On the packaging of the ATCA, RCA was directed to abandon their segmented ERA approach and adapt a configuration conforming to the packaging specification (LSP-360-002). In response they submitted a list of questions (Reference a) concerning this specification; a number of these questions fell into the domain of Reliability.

4.12.1.2.3.1 Updated Packaging Study (continued)

and its subcontractors for the two ERA's comprising the Communications Subsystem, and its major subassemblies. The designs presented in that report were essentially amplifications of designs that had been presented by RCA during the previous quarter. GAEC had raised numerous objections to these designs at the times of those prior submissions (References f and g). It was deemed necessary once more to raise these objections, and a point-by-point listing of them was submitted to RCA in Reference (h).

4.12.1.2.3.2 New Requirements

On 21 August 1964 RCA submitted their proposal for implementation of the NASA new subsystem requirements. (CCA 61). One volume of this submission contained the technical proposal. RCA continued to propose the same type of packaging (segmented, etc.) which they had been proposing prior to the new requirements.

The second volume of the RCA submission contained a list of changes to LSP-380-2, the equipment specification plus changes to LSP-360-002, the general packaging specification. RCA requested many of the former changes to accommodate their deviations from LSP-360-002. They claimed the later changes were required by the former changes. Reliability Control has cautioned design engineering that deviations from specifications should be supported by waiver requests and that the general specification should not be changed each time a vendor wants to deviate from it.

4.12.1.2.3.3 S-Band Erectable Antenna

Another portion of the Communications Subsystem which was scrutinized for packaging reliability was the S-Band Erectable Antenna. This scrutiny culminated in attendance by Reliability personnel at a demonstration of dish operation at GAEC, Bethpage. The demonstration showed that the packaging of the antenna presents many problems in reliability. These problems were discussed in a memo to the subsystem engineering group (Reference i).

4.12.1.2.4.1 General Purpose Inverter (continued)

resistance to damage during maintenance handling, and it was suggested that they devote further effort to finding a way to use stranded wire.

4.12.1.2.4.2 Vehicle Wiring Specification

A GAEC specification on wiring and wiring devices (LSP-390-002) generated by the GAEC electrical power subsystems engineering group, was reviewed by LEM Reliability Control. The major objection to this specification raised by Reliability Control was that the specification would encourage free use of single and multiple crimp type butt splices. The electrical power subsystem engineering group wants to use these splices for multiple-branching of wire runs. Reliability Control does not favor this practice. Coordination will continue in this and other areas until a resolution acceptable to Reliability Control is achieved.

4.12.1.2.4.3 Solenoid Valve Electrical Wiring

The GAEC electrical power subsystem engineering group has requested that the propulsion helium flow control valves be fitted with flying leads instead of separable connectors in the interest of weight saving. They propose to connect these leads to the proper wires in the vehicle harness by means of crimp-type butt splices. Again, Reliability does not favor this practice, preferring that the valves be fitted with terminals and the harness carry the flying leads, for the following reasons. Flying leads on the valve will be more susceptible to handling damage than terminals; the harness will require flying leads in either case. Harness bulk will be reduced by valve terminals, through elimination of additional lead lengths required to permit cutting out splices for valve replacement. An Maintainability will be improved with terminals.

4.12.1.3 Projected Effort For Next Period (continued)

3. (continued)

temperatures well in excess of oven temperatures; in some cases, these temperatures have been known to go beyond the survival temperature of parts especially sensitive to temperature. Through coordinated effort among packaging, parts, and materials and processes people, effort will be applied to this problem. It is hoped that material and process specifications will result, which will provide adequate controls to prevent degradation of reliability caused by excessive potting temperatures.

4.12.1.4 Formal Meetings Attended

August 25 - 26	Specification Negotiations With Space Technology Laboratories - Abort Electronics Assembly. Reference c & d.
August 28	Design Presentation by Hamilton Standard Division - General Purpose Inverter; Electron Beam Welded Micromodules.
September 1	Technical Coordination Meeting With Personnel From GAEC - Peconic Program Coupler Assembly.
September 3	Technical Coordination Meeting With Francis Associates - Design of Service Test Models of ERA.
September 18	Technical Coordination Meeting With RCA and Rantec, Inc. - Design of Multiplexers For Communications Subsystem.

4.12.1.5 References

a. Clarification and Information Requirements - LSP-360-002, dated November 18, 1963, informal communication from F. L. Pratt to R. Paganetti, LIC-(B)-6100-178, RCA, dated 1 September 1964.

5.0 DOCUMENTATION RELEASED DURING THE REPORT PERIOD

5.1 Memorandums

Number	Date	Title
LMO-550-376	8-4-64	GAEC Review of Parts Specification Nos. 106127, 106146, 106067, 106166, 102784, 106159 106118 and 106161-5 TYPE I DOCUMENT
LMO-550-377	8-4-64	GAEC Review of Radiation, Inc. Parts Procurement Specifications Except Where Specifically Noted Approval is Withheld on the Following Listed Specifications Pending Incorporation or Satisfactory Response to Following Comments. TYPE I DOCUMENT
LMO-550-378	8-4-64	GAEC Review of Radiation, Inc. Specifications Submitted in References (a), (b) and (c). TYPE I DOCUMENT
LMO-550-379	8-4-64	GAEC Review of Radiation, Inc. ECO's for 106105, 104124, 106121, and 104118.
LMO-550-380	8-4-64	Radiation, Inc. Request to Add Fairchild Semiconductor as an Alternate Source for Radiation Part 106101. TYPE I DOCUMENT
LMO-550-381	8-4-64	PCM Special Test Equipment Parts Specifications Submitted by Radiation, Inc. TYPE I DOCUMENT
LMO-550-382		CANCELLED
LMO-550-383		CANCELLED

5.1 Memorandums (continued)

Number	Date	Title
LMO-550-394	8 - 64	Reliability Task Description and Manpower Estimate for LEM Radiator/Water Boiler Configuration Studies.
LMO-550-395	9 - 64	Engine Configuration Analysis for LEM Ascent Engine.
LMO-550-396	9-9-64	D'Arsonval Meter Parts Cost Estimate
LMO-550-397	9-10-64	Test Points of Electronic Equipment
LMO-550-398		CANCELLED
LMO-550-399	9-10-64	Reliability Control Comparison of Coaxial RF Switch Proposals Designed in Accordance With GAEC Specification No. LSP-380-7A.
LMO-550-400	9-14-64	Reliability Revision to LSP-360-8
LMO-550-401	9-14-64	LEM Ascent Engine Instrumentation Reliability
LMO-550-402	9-15-64	Reliability Control's Comments on Aerojet-General's Drawing 515640 Tank Half-Lower
LMO-550-403	9-16-64	Additional Reliability Agreements of RCA. Dalmo Victor/ GAEC Steerable Antenna Meeting of 26 August 1964 at Burlington Massachusetts
LMO-550-404	9-18-64	Reliability Analysis of PCA Decoding and Input Circuits

5.1 Memorandums (continued)

Number	Date	Title
LMO-550-416	9-29-64	LEM-GSE Parts Selection and Application Policy
LMO-550-417	9-30-64	Transmittal of Change of Section D of P.O. 2-18832-C
LMO-550-418	9 - 64	PCM Weak Link Redundancies
LMO-550-419		PROPRIETARY
LMO-550-420	9-30-64	Display of Descent & Ascent Engines Bi-Propellant Valve Positioning on Crew System's Display Panel
LMO-550-421	10-2-64	Amendment to LSP-350-801A
LMO-550-422	10-2-64	Amendment to LSP-350-305A
LMO-550-423	10-2-64	Amendment to LVR-350-303, Incremental Velocity Indicator
LMO-550-424		PROPRIETARY
LMO-550-425	10-5-64	NASA-MSC-ASPO Grumman Reliability Meeting at Grumman 23 and 24, 1964
LMO-550-426	10-5-64	Tube Joining Methods for RCS Subsystem
LMO-550-427	10-6-64	Deletion of Primary Heat Transport Loop Operation Prior to Checkout in Lunar Orbit
LMO-550-428	10-6-64	Reliability Requirements for Landing Radar Operation Time

5.1 Memorandums (continued)

Number	Date	Title
LMO-550-440	10-20-64	Effect of a Non-Free Return Trajectory on LEM Reliability
LMO-550-441		PROPRIETARY
LMO-550-442	10-24-64	PCM Mission Success Criteria and Reliability
LMO-550-443	9-1-64	Status of the Reliability Effort of the Internal Environmental Simulator (IES)
LMO-550-444	10-26-64	LEM Reliability Specification for DECA LSP-300-13, Recommended Change To
LMO-550-445	10-29-64	Failure of One or Two of the ATCA Rotational Channels